S mark
Safety Certification System in Korea

KOREA OCCUPATIONAL
SAFETY & HEALTH AGENCY

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Occupational Safety and Health Act

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Article 34-2 (Safety certification of machinery and equipment)

① The Minister of Labor can approve the use of safety mark for the machinery and equipment which comply with the safety and health standard prescribed by the ministerial decree.

② The Manufacture of machinery and equipment who wishes to get a certification according to paragraph 1 shall apply to the Minister of Labor.

③ Certification items, application procedures and administrative matters necessary for certification shall be specified in the ministerial decree.

Article 34-3 (The use of safety mark)

The manufacturer who had obtained a certificate according to the paragraph 1, Article 34-2 can affix safety mark on the machines and equipment, on package and on containers specified in the ministerial decree or can advertise the certification of the use of safety mark.

Article 34-4 (Prohibition of use of safety mark)

It is prohibited to affix safety mark or similar mark on the package and containers of machinery and equipment, or to advertise the use of safety mark unless manufacturer is anyone who had obtained certification for the use of safety mark.

Article 34-5 (Certification cancellation of safety mark)

The Minister of Labor shall cancel the use of safety mark certification and shall notify the cancelled matters to the manufacturer in accordance with ministerial decree in case the manufacturer who had obtained a certificate according to the Law, Article 34-2, Paragraph 1 had obtained certification by one of the following paragraphs;

1. Certification proved false.
2. Machinery and equipment carried with certification mark become not to be complied with the standard according to the Article 34-2, Paragraph 1.

Article 34-6 (Removal of certification mark, etc)

The Minister of labor shall take a necessary action including removal order of certification mark in case machinery and equipment which certification mark of similar mark has been affixed without getting a certificate according to the Article 34-2 or in case machinery and equipment which certification has been cancelled according to the Article 34-5.

Article 66 (Fee, etc)

① Any person who falls under any of the following Subparagraphs, shall pay the fee under the conditions as prescribed by the Order of the Ministry of Labor:

Person who desires to receive the certification of use of the safety certificate under Article 34-2.

Enforcement Decree for Occupational Safety and Health Act

Article 47 (Commission of administrative authority)

Matters which are commissioned to the Korea Occupational Safety and Health Agency or not-for-profit corporation are as follows;
Receiving and deliberating the applicants for the license of the use of safety marks and certificating them
pursuant to the Article 34-2.

Enforcement Regulation for Occupational Safety and Health Act

Article 46-2 (Inspection of Performance of Protection Equipment)

For the following protection equipment, the inspection of the performance may be exempted: 1~7.

1. Protection equipment incorporated with the machines, equipment or facilities which have been inspected of their design, completion and performance as set forth in the Paragraph 3 of the Article of the Act.
2. The protection equipment which have been granted the use of safety marks pursuant to the Paragraph 1 of the Article 34-2of the Act including the protection equipment incorporated with the machines, equipment or facilities which have been granted the use of safety marks with the protection equipment being incorporated.

Article 59 (Exemption of double inspections)

③ The design and performance inspections as set in the paragraph 3 of the article 34 may be exempted for the machines and equipment which have been allowed the use of safety marks pursuant to the paragraph 1 of the article 34-2 of the act.

Article 59-2 (Machinery and equipment to have certification of use of safety mark)

Machinery and equipment to which the use of safety marks may be allowed pursuant to the

article 34-2 of the act shall be as follows:

1. Machinery and equipment in annexed table 7 of the decree.
   ① Press or shearing machine
   ② Acetylene welder or gas collective welder
   ③ Explosion proof electrical machine and equipment
   ④ Alternating current arc welder
   ⑤ Crane, Elevator, Gondola, Lift
   ⑥ Pressure vessel
   ⑦ Boiler
   ⑧ Roller
   ⑨ Grinder
   ⑩ Wood-working circular saw
   ⑪ Portable power planer
   ⑫ Industrial robot which complex movement can be performed
   ⑬ Insulation equipment for electrical line work
   ⑭ Temporary construction equipment for the prevention of fall or collapse
2. Electro-sensitive, two-hand control and gate guard protective device, etc.
3. Machinery and equipment which the Minister of Labor determined after listening opinion of the body commissioned(hereinafter called "Certification Body") as the industrial machinery and equipment which industrial accidents had been occurred frequently.

Article 59-3 (Standards of safety certifications)

The "machines and equipment which meet the safety and health standards as set forth by the Ordinances of the Ministry of Labor" in the Paragraph 1 of the Article 32-2 of the Law shall mean the machines and equipment as set forth in the Article 59-2 herein which meet the following requirements :

1. The design and production shall be such that the danger and hazard which are possible during the use or handling may be eliminated or protected to reduce the danger.
2. The design and production shall consider the fatigue, stress and inconvenient posture during the use and handling.

3~9.

10. The quality control and after sales maintenance system will be established.

Article 59-4 (Application for Safety Certification)

Those who wish to apply for the safety certification pursuant to the paragraph 2 of the Article 34-2 of the Law shall submit to the Safety Certification Organizations following document:

1. Copies of the business register
2. Descriptions on the structure, materials, dimensions, performance and manual for the use of the products concerned;

3. Data on the safety inspection including the design standards, safety testing methods and quality control methods ;
4. Results of safety tests performed by the manufacturers and independent institutes(if any tests have been performed) ;
5. Copies of the performance inspection as set forth in the Paragraph 3 of the Article 33 of the Law and of the test conformity certificates as set forth in the Article 34 of the Law(if any) ;
6. Documents proving any certifications from domestic or foreign institutes (if any) ; and
7. Manuals for safe use of the products including the safety checklists, etc.

② If the Safety Certification Organizations view the documents provided with the application as insufficient, the Organizations may have the applicable applicant supplement them.

Article 59-5 (Issue of Safety Certificates)

The Safety Certification Organizations shall examine the applied items within 6 months from the reception of the application and, if the Organizations judge that the items satisfy the safety and health standards as set forth in the Article 59-3, issue the safety certificates in the amended form no. 10-3.

Article 59-6 (Method of Examination)

① The examination for the safety certification shall be conducted for each different type and model of machines and equipment.

② The examination as mentioned in the preceding Paragraph 1 may include the field examination and inspection on the products, as well as the document examination.

③ With regard to the products which have been recognized by domestic and foreign certifications which are enumerated by the Minister of Labor, the whole or part of the examination as set forth in the preceding Paragraph 1 may be exempted.

Article 59-7 (Safety Marking, etc.)

① The marking of the safety marks pursuant to the Article 34-3 of the Law shall follow the methods in the annexed Table 8-3.

② When the advertising is made with regard to the safety certifications pursuant to the Article 34-3 of the law, the contents of the certifications shall be specifically and distinctively indicated.

Article 59-8 (Follow-up Control for safety Certifications)

① In order to confirm that the certified items satisfy the safety and health standards as set forth in the Paragraph 1 of the Article 34-2, the Minister of Labor shall have the Safety Certification Organizations conduct the follow-up examination at least once a year.

② If the heads of the local labor offices view that the safety of any certified products should

be confirmed including the occurrence of any serious accidents related to the certified products, they may request the Safety Certification Organizations to perform the follow-up examination to confirm if any certified products still satisfy the safety and health standards as set forth in the Paragraph 1 of the Article 34-2 of the Act.

Article 59-9 (Cancellation of Safety Certifications)

① When the heads of the Safety Certification Organizations have found any machines or equipment for which the safety certifications should be cancelled pursuant to the Article 34-5 of the Act, they shall report such machines or equipment to the heads of the local labor offices.

② If the heads of the local labor offices have cancelled the safety certifications, they shall notify to the Safety Certification Organizations the said cancellation within 10 days therefrom and the heads of the Safety Certification Organizations shall announce the followings on a daily newspaper, etc. within 30 days from the notice of the cancellation :

1. Safety certificate number ;
2. Product names and model number of the products for which the certificate has been cancelled ;
3. Manufacturers ;
4. Dates of cancellations ; and
5. Reasons for cancellations

③ The manufactures whose safety certifications have been cancelled pursuant to the Article 34-5 of the Act shall immediately return to the heads of the local labor offices the safety certificates as set forth in the Article 59-5 herein.

Article 59-10 (Support for the Safety Certified Products)

In order to promote the use of safety certified products, the Minister of Labor may request the related and other public authorities to provide necessary co-operation including the preferred purchase of the safety certified products.

Article 59-11 (Detailed Rules)

The Safety Certification Organizations may determine the detailed rules for the standard of the safety certifications, certification fees and others with the approval from the Minister of Labor.

Safety Certification Technical Requirements for Machinery and Equipment, etc.

Safety Certification Technical Requirements for Machinery and Equipment, etc.

Chapter 1. Essential Safety Certification Requirements for Machinery and Equipment, etc. (S1-G-35-2003)

Section 1. Essential Safety and Health Requirements for Design and Manufacturing

Sub-section 1. General Principles

1. Safety Securing Principles

1.1 Machinery must be so constructed that it is suitable for its function, and can be adjusted and maintained without placing persons at risk when its operations are carried out under the conditions foreseen by the manufacturer. The aim of measures taken must be to eliminate any risk of accident throughout the foreseeable lifetime of the machinery, including the phases of assembly and dismantling, even where risks of accident arise from unforeseeable abnormal situations.

1.2 In selecting the most appropriate methods, the manufacturer must apply the following principles, in the order given.

(1) Eliminate or reduce risks as far as possible.
(2) Take necessary protection or precautionary measures in relation to risks that cannot be eliminated.
(3) Inform users of residual risk due to any shortcomings of protection measures adopted, indicate, and present the necessity of training for specific subject and personal protective equipment(hereinafter referred to as "PPE").

1.3 When designing and constructing machinery, and when drafting instructions, the manufacturer must consider following requirements.

(1) Machinery must be designed to prevent not only normal use but also abnormal use which would engender a risk.
(2) Instructions which employees must observe are to be included in the user's manual, if there are any possibilities of risk.

1.4 Under the intended conditions of use, the discomfort, fatigue and psychological stress

faced by the operator must be reduced to a minimum taking ergonomic principles into account.

1.5 When designing and constructing machinery, the manufacturer must take into account of the constraints to which an operator is subject as a result of the necessary or foreseeable use of PPE (such as footwear, gloves, etc).

1.6 Machinery must be supplied with all essential specialised equipment and accessories to enable adjustment, maintenance and use without risk.

2. Materials and Products

2.1 The materials used to construct machinery or products used and created during its use must not endanger exposed persons' safety or health.

2.2 In particular, where fluids are used, machinery must be designed and constructed for use without risk due to filling, use, re-filling or draining.

3. Lighting

3.1 The manufacturer must supply integral lighting suitable for the operations concerned where its lack is likely to cause a risk despite ambient lighting of normal intensity.

3.2 The manufacturer must ensure that there is no area of shadow likely to cause impair vision/task performance, which there is no irritating dazzle and that there are no dangerous stroboscopic effects due to the lighting provided by the manufacturer.

3.3 Internal parts requiring frequent inspection, and adjustment and maintenance areas, must be provided with appropriate lighting.

4. Design of machinery to facilitate its handling

4.1 Machinery or each component part thereof must be capable of being handled and safely, be packaged or designed so that it can be stored safely and without damage (e.g. adequate stability, special supports, etc).

4.2 Where the weight, size or shape of machinery or its various component parts prevent them from being moved by hand, the machinery or each component part must be appropriate to one of the following cases;

(1) Lifting accessories shall be fitted to the machinery or the machinery shall have a structure whereby lifting accessory can be fitted firmly.
(2) It shall be a structure like as threaded holes that allow lifting accessories to be fitted

easily.

4.3 Machinery or components to be moved by hand shall be as follows;

(1) Must be easily movable.
(2) Must be equipped for carriage (e.g. hand, etc) and movement in complete safety.

4.4 Special arrangements must be made for the handling of tools and/or machinery parts, regardless of lightweight that may be dangerous (shape, material, etc).

Sub-section 2 Controls

5. Safety and reliability of control systems

Control systems must be designed and constructed so that they are safe and reliable, in a way that will prevent a dangerous situation arising. Above all they must be designed and constructed to conform to the following specifications.

(1) Be able to withstand the rigours of normal use and external factors.
(2) Errors in logic will not lead to the development of dangerous situations.

6. Control devices

6.1 Control devices must be as follows.

(1) Clearly visible and identifiable and appropriately marked where necessary.
(2) Positioned for safe operation without hesitation or loss of time, and without ambiguity.
(3) Designed so that the movement of the control is consistent with its effect.
(4) Located outside danger zones, except for certain controls where necessary, such as emergency stop or a console for the training of robots.
(5) Positioned so that their operation cannot cause additional risk.
(6) Designed or protected so that the desired effect, where a risk is involved, cannot occur without an intentional operation.
(7) Made so as to withstand foreseeable strain; particular attention must be paid to emergency stop devices liable to be subjected to considerable strain.

6.2 Where a control is designed and constructed to perform several different actions, namely where there is no one correspondence (e.g. keyboards, etc), the action to be performed must be clearly displayed and subject to confirmation if necessary.
6.3 Controls must be so arranged that their layout, travelling route and resistance to operation

are compatible with the action to be performed, taking ergonomic principles into account. Constraints due to the necessary or foreseeable use of PPE must be taken into account.

6.4 Machinery must be fitted with indicators (dials, signals, etc) as required for safe operation. The operator must be able to read them from the control position.

6.5 Where an operator may be exposed to a danger zone, machinery must conform to the following specifications.

(1) The operator located at the main control position must be able to ensure that there are no exposed persons in the danger zones.
(2) If this is not possible, the control system must be designed and constructed so that an acoustic and/or visual warning signal is given whenever the machinery is about to start. The exposed person must have the time and the means to take rapid action to prevent machinery starting up.

7. Starting

7.1 It must be possible to start machinery only by actuation of a control provided for the purpose.

7.2 The same requirement applies to Paragraph 1 when restarting the machinery after a stoppage, whatever the cause, and when effecting a significant change in the operating conditions (e.g. speed, pressure, etc) unless such restarting or a change in operating conditions is without risk to exposed persons. This essential requirement does not apply to the restarting of the machinery or to the change in operating conditions resulting from the normal sequence of an automatic cycle.

7.3 Where machinery has several starting controls and the operators can therefore place each other in danger, additional devices (e.g. enabling devices or selectors allowing only one part of the starting mechanism to be actuated at any one time) must be fitted to rule out such risks.

7.4 It must be possible for automated plant functioning in automatic mode to be restarted easily after a stoppage once the safety conditions have been fulfilled.

8. Stopping device

8.1 Normal stopping devices shall be as follows.

(1) Each machine must be fitted with a control whereby the machine can be brought safely to a complete stop.
(2) Each work station must be fitted with a control to stop some or all of the moving parts of

the machinery, depending on the type of hazard. The machinery's stop control must have priority over the start controls.

(3) Once the machinery or its dangerous parts have stopped, the energy supply to the actuators concerned must be cut off.

8.2 Each machine must be fitted with one or more emergency stop devices to enable actual or impending danger to be averted. The following exceptions apply:

(1) Machines in which an emergency stop device would not lessen the risk, either because it would not reduce the stopping time or because it would not enable the special measures required to deal with the risk to be taken;
(2) Hand portable machines and hand machines.

8.3 Emergency stop device must conform to the following specifications.

(1) Emergency devices have clearly identifiable, clearly visible and quickly accessible controls.
(2) Emergency devices must stop a dangerous process as quickly as possible, without creating additional hazards.
(3) Emergency devices must, where necessary, trigger or permit the triggering of certain safeguard movements.
(4) Once active operation of the emergency stop control has ceased following a stop command, that command must be sustained by engagement of the emergency stop device until that engagement is specifically overridden.
(5) It must not be possible to engage the device without triggering a stop command.
(6) It must be possible to disengage the device only by an appropriate operation, and disengaging the device must not restart the machinery but only permit restarting.

8.4 In the case of machinery or parts of machinery designed to work together, the manufacturer must so design and construct the machinery that the stopping controls including the emergency stop, can stop not only the machinery itself but also all the movement of inter locked machines if its continued operation can be hazardous.

9. Mode selection

9.1 The control mode selected must override all other control systems with the exception of the emergency stop.

9.2 If machinery has been designed and built to allow for its use in several control or operating modes presenting different safety levels (e.g. to allow for repair, adjustment, maintenance, inspection etc), it must be fitted with a mode selector which can be locked in each position. Each position of the selector must correspond to a single operating or control

mode.

9.3 In case of operations in which the machinery must be able to operate with its protection devices neutralised, the control mode is as follow:

(1) Disable the automatic control mode.
(2) Permit movements only by controls requiring sustained action.
(3) Permit the operation of dangerous moving parts only in enhanced safety conditions (e.g. reduced speed, reduced power, or other adequate provisions) while preventing hazards from linked sequences.
(4) Prevent any movement liable to pose a danger by acting voluntarily or involuntarily on the machine's internal sensors.

9.4 In addition, the operator must be able to control the operation of the working parts at the control area.

10. Failure of the power supply

The interruption, re-establishment after an interruption or fluctuation in whatever manner of the power supply to the machinery must not lead to a hazardous situation. The following requirements must be complied with.

(1) The machinery must not start unexpectedly.
(2) The machinery must not be prevented from stopping if the command has already been given.
(3) No moving part of the machinery or piece held by the machinery must fall or be ejected.
(4) Automatic or manual stopping of the moving parts whatever they may be must be unimpeded.
(5) The protection devices must remain fully effective.

11. Failure of the control circuit

A fault in the control circuit logic, or failure of or damage to the control circuit must not lead to a hazardous situations. The following requirements must be complied with.

(1) The machinery must not start unexpectedly.
(2) The machinery must not be prevented from stopping if the command has already been given.
(3) No moving part of the machinery or piece held by the machinery must fall or be ejected.
(4) An automatic or manual stopping of the moving parts whatever they may be must be unimpeded.
(5) The protection devices must remain fully effective.

12. Software

Interactive software between the operator and the command language or control system of a machine must be user friendly.

Sub-section 3 Protection against mechanical hazards

13. Stability

Machinery, components and fittings thereof must be so designed and constructed that they are stable enough, under the foreseen operating conditions (if necessary taking climatic conditions into account) for use without risk of overturning, falling or unexpected movement. If the shape of the machinery itself or its intended installation does not offer sufficient stability, appropriate means of anchorage must be incorporated and indicated in the instructions.

14. Risk of break-up during operation

14.1 The various parts of machinery and their linkages must be able to withstand the stresses to which they are subject when used as foreseen by the manufacturer.

14.2 The durability of the materials used must be adequate for the nature of the work place foreseen by the manufacturer, in particular as regards the phenomena of fatigue, ageing, corrosion and abrasion.

14.3 The manufacturer must indicate in the instructions the type and frequency of inspection and maintenance required for safety reasons. He must, where appropriate, indicate the parts subject to wear and the criteria for replacement.

14.4 Where a risk of rupture or disintegration remains despite the measures taken (e.g. as with grinding wheels) the moving parts must be mounted and positioned in such a way that in case of rupture their fragments will be contained.

14.5 Both rigid and flexible pipes carrying fluids, particularly those under high pressure, must be able to withstand the foreseen internal and external stresses and must be firmly attached and/or protected against all manner of external stresses and strains: precautions must be taken to ensure that no risk is posed by a rupture (sudden movement, high jets, etc).

14.6 Where the material to be processed is fed to the tool automatically, the following conditions must be fulfilled to avoid risks to the persons exposed (e.g. tool breakage).

(1) when the workpiece comes into contact with the tool the latter must have attained its normal working conditions;

(2) when the tool starts and/or stops (intentionally or accidentally) the feed movement and the tool movement must be co-ordinated.

15. Risks due to falling or ejected objects

Precautions must be taken to prevent risks from falling or ejected objects (e.g. workpieces, tools, cuttings, fragments, waste, etc).

16. Risks due to surfaces, edges or angles

In so far as their purpose allows, accessible parts of the machinery must have no sharp edges, no sharp angles, and no rough surfaces likely to cause injury.

17. Risks related to combined machinery

Where the machinery is intended to carry out several different operations with the manual removal of the piece between each operation(combined machinery), it must be designed and constructed in such a way as to enable each element to be used separately without the other elements constituting a danger or risk for the exposed personnel. For this purpose it must be possible to start and stop separately any elements that are not protected.

18. Risks relating to variations in the rotational speed of tools

When the machine is designed to perform operations under different conditions of use(e.g. different speeds or energy supply), it must be designed and constructed in such a way that selection and adjustment of these conditions can be carried out safely and reliably.

19. Prevention of risks related to moving parts

19.1 The moving parts of machinery must be designed, built and laid out to avoid hazards or, where hazards persist, fixed with guards or protective devices in such a way as to prevent all risk of contact which could lead to accidents.

19.2 In cases where, despite the precautions taken, a blockage is likely to occur, specific protection devices or tools, the manufacturer should provide the instruction handbook and important signage on the machinery.

20. Choice of protection against risks related to moving parts

20.1 Guards or protection devices used to protect against the risks related to moving parts must be selected on the basis of the type of risk. The following guidelines must be used to help make the choice.

(1) Guards designed to protect exposed persons against the risks associated with moving transmission parts (such as pulleys, belts, gears, rack and pinions, shafts, etc) must be either fixed, complying with requirements Article 21 and 22.1 or movable, complying with requirements 21 and 22.2.
(2) Guards or protection devices designed to protect exposed persons against risks associated with moving parts contributing to the work (such as cutting tools, moving parts of presses, cylinders, parts in the process of being machined, etc) must fulfil the following requirements.

A. Wherever possible fixed guards shall comply with requirements in the 21 and 22.1.
B. Otherwise, movable guards shall comply with requirements Article 21 and type A in 22.2.
C. Protection devices such as sensing devices, position controlled protection devices (e.g. two hand controls), or protection devices in accordance with requirements 21 and 22.4 shall be installed.

20.2 However, when certain moving parts directly involved in the process cannot be made completely or partially inaccessible during operation owing to operations requiring nearby operator intervention, where technically possible such parts must be fitted with following guards.

(1) Fixed guards, complying with requirements Article 24 and paragraph 1 of Article 25 preventing access to those sections of the parts that are not used in the work.
(2) Adjustable guards, complying with requirements Article 24 and paragraph 3 of Article 25 restricting access to those sections of the moving parts that are strictly for the work.

Sub-section 4 Guards and protection devices

21. General requirement

Guard and protection device must fulfil the following requirements.

(1) It must be of robust construction.
(2) It shall not give rise to any additional risk.
(3) It shall not be easy to defeat the function.
(4) It shall be located at an adequate distance from the danger zone.
(5) It shall cause minimum obstruction to the view of the production process.
(6) It shall enable essential work to be carried out on installation and/or replacement of tools and also for maintenance by restricting access only to the area where work is to be done, if possible without the guard or protection device having to be dismantled.

22. Special requirements for guards

22.1 A fixed guard must fulfil the following requirements.

(1) It must be securely held in place.
(2) It must be fixed by systems that can be opened only with tools.
(3) Where possible, guards must be unable to remain in place without their fixings.

22.2 Movable guard shall fulfil the following requirements.

(1) Type A movable guards must as far as possible remain fixed to the machinery when open and must be associated with a locking device to prevent moving parts starting up as long as these parts can be accessed and to give a stop command whenever they are no longer closed.
(2) Type B movable guards must be designed and incorporated into the control system so that:

A. moving parts cannot start up while they are within the operator's reach.
B. the exposed person cannot reach moving parts once they have started up.
C. they can be adjusted only by means of an intentional action, such as the use of a tool, key, etc.
D. the absence or failure of one of their components prevents starting or stops the moving parts.
E. protection against any risk of ejection is provided by means of an appropriate barrier.

22.3 An adjustable guard restricting access such as cover for sawing blades shall fulfil the following requirements.

(1) It must be adjustable manually or automatically according to the type of work involved.
(2) It must be readily adjustable without the use of tools.
(3) It must reduce as far as possible the risk of ejection.

22.4 Protection devices must be designed and incorporated into the control system so that:

(1) moving parts cannot start up while they are within the operator's reach.
(2) the exposed person cannot reach moving parts once they have started up.
(3) they can be adjusted only by means of an intentional action, such as the use of a tool, key, etc.
(4) the absence or failure of one of their components prevents starting or stops the moving parts.

Sub-section 5 Protection against other hazards

23. Electricity supply

23.1 Where machinery has an electricity supply it must be designed, constructed and equipped so that all hazards of an electrical nature are or can be prevented.

23.2 The specific rules in force relating to electrical equipment designed for use within certain voltage limits must apply to machinery which is subject to those limits.

24. Static electricity

Machinery must be so designed and constructed as to prevent or limit the build of potentially dangerous electrostatic charges and/or be fitted with a discharging system.

25. Energy supply other than electricity

Where machinery is powered by an energy other than electricity (e.g. hydraulic, pneumatic or thermal energy, etc), it must be so designed, constructed and equipped as to avoid all potential hazards associated with these types of energy.

26. Errors of fitting

26.1 Errors likely to be made when fitting or refitting certain parts that maybe a source of risk must be made impossible by the design of such parts or, failing this, by information given on the parts themselves and/or the housings.

26.2 The same information must be given on moving parts and/or their housings where the direction of movement must be known to avoid a risk. Any further information that may be necessary must be given in the instructions.

26.3 Where a faulty connection can be the source of risk, incorrect fluid connections, including electrical conductors, must be made impossible by design or, failing this, by information given on the pipes, cables, etc, and/or connector blocks.

27. Dangerous temperatures

27.1 Steps must betaken to eliminate any risk of injury caused by contact with or roximity to machinery parts or materials at high or very low temperatures.
27.2 The risk of hot or very cold material being ejected should be assessed. Where this risk exists, the necessary steps must be taken to prevent it or, if this is not technically possible, to render it non

28. Fire

Machinery must be designed and constructed to avoid all risk of fire or overheating posed by the machinery itself or by gases, liquids, dusts, vapours or other substances produced or used by the machinery.

29. Explosion

29.1 Machinery must be designed and constructed to avoid any risk of explosion posed by the machinery itself or by gases, liquids, dusts, vapours or other substances produced or used by the machinery.

29.2 The manufacturer must take the following steps.

(1) Avoidance of a dangerous concentration of hazardous substances.
(2) Prevention of the existence of ignition sources within the potentially explosive atmosphere.
(3) Minimization of any explosion possibility which may occur so that it does not endanger the surroundings.

29.3 The same precautions in paragraph 2 must be taken if the manufacturer foresees the use of the machinery in a potentially explosive atmosphere.

29.4 Electrical equipment forming part of the machinery must conform, as far as the risk from explosion is concerned, to the provision of the specific legislation in force.

30. Noise

Machinery must be so designed and constructed that risks resulting from the emission of airborne noise are reduced to the lowest level taking into account the technical progress and the availability of means of reducing noise, in particular at its source.

31. Vibration

Machinery must be so designed and constructed that risks resulting from vibrations produced by the machinery are reduced to the lowest level, taking into account the technical progress and the availability of means to reduce vibration, in particular at its source.

32. Radiation

Machinery must be so designed and constructed that any emission of radiation is limited to the extent necessary for its operation and that the effects on exposed persons are nonexistent or reduced to nonproportions.

33. Electromagnetic compatibility

33.1 Machinery must be so designed and constructed that electromagnetic disturbances shall not interfere with safe operation of machinery, or safe operation of machinery shall not be affected from external electromagnetic radiation.

33.2 Tests for electromagnetic compatibility according to 33.1 are divided into tests for electromagnetic disturbances and test for electromagnetic immunity. Test items are as follows;

(1) Machinery and equipment to be tested for electromagnetic disturbances

A. Processing machine using high frequency energy such as an industrial electrical induction heater, industrial high frequency heater, RF excited welder.
B. Arc or spark producing machines during work processes such as an electro discharge machine, electrical welding machine.
C. Machinery and equipment for which applicants may desire a test for electromagnetic disturbances.

(2) Machinery and equipment to be tested for electromagnetic immunity

A. Industrial robots (machinery incorporated industrial robots included)
B. Automatic control type (NC or CNC) of machine tool
C. Machinery and equipment using wireless remote control device.
D. Safety (Protective) devices using electrical/electronic control circuits
E. Automatic transportation equipment (only using electricity/magnetic field as power)
F. Machinery and equipment for which applicants may desire a test for electromagnetic immunity.

(3) Machinery and equipment to be tested for electromagnetic disturbances and immunity:

A. Machinery and equipment to comply with both requirements Number 1 and 2 of 33.2.
B. Machinery and equipment for which applicants may desire a test for electromagnetic disturbances and immunity.

34. Laser equipment

Where laser equipment is used, the following provisions should be taken into account.

(1) Laser equipment on machinery must be designed and constructed so as to prevent any accidental radiation.
(2) Laser equipment on machinery must be protected so that effective radiation, radiation produced by reflection or diffusion and secondary radiation are not hazardous to health.
(3) Optical equipment for the observation or adjustment of laser equipment on machinery must be such that the laser rays create no health risk.

35. Emissions of dust, gases, etc

35.1 Machinery must be so designed, constructed and/or equipped such that risks due to gases, liquids, dust, vapours and other waste materials produced are avoidable.

35.2 Where a hazard exists, the machinery must be so equipped that the said substances can be contained and/or evacuated.

35.3 Where machinery is not enclosed during normal operation, the devices for containment and/or evacuation must be situated as close as possible to the source of the emission.

36. Risk of being trapped in a machine

Machinery must be designed, constructed or fitted with a means of preventing exposed personnel from being enclosed within it or, if that is impossible, with a means of requesting help.

37. Risk of slipping, tripping or falling

Parts of the machinery where persons are liable to move about or stand in proximity to must be designed and constructed to prevent persons slipping, tripping or falling on or off these parts.

Sub-section 6 Maintenance

38. Machinery maintenance

38.1 Adjustment, lubrication and maintenance must be carried out outside danger zones. It must be possible to carry out adjustment, maintenance, repair, cleaning and servicing operations while machinery is at a standstill. If one or more of the above conditions cannot be satisfied for technical reasons, these operations must be possible without risk.

38.2 In the case of automated machinery and, where necessary, other machinery, the manufacturer must make provisions for a connecting device to mount diagnostic fault equipment.

38.3 Automated machine components that have to be changed frequently, in particular for a change in manufacture or where they are liable to wear or likely to deteriorate following an accident, must be capable of being removed and replaced easily and in safety. Access to the components must enable these tasks to be carried out with the necessary technical means

(tools, measuring instruments, etc) in accordance with an operating method specified by the manufacturer.

39. Operating position, etc.

The manufacturer must provide means of access (stairs, ladders, cat walks, etc) to allow access in safety to all areas used for production, adjustment and maintenance operations.

40. Isolation of energy sources

All machinery must be fitted with the following means to isolate it from all energy sources. In the case of machinery supplied with electricity through a plug capable of being inserted into a circuit, separation of the plug is sufficient.

(1) Such isolators must be clearly identified.
(2) They must be capable of being locked if reconnection could endanger exposed personnel.
(3) The isolator must be capable of being locked also where an operator is unable, from any of the points to which he has access, to check that the energy is still cut off.
(4) After the energy is cut off, it must be possible to dissipate normally any energy remaining or stored in the circuits of the machinery without risk to exposed persons. As an exception to the above requirements, certain circuits may remain connected to their energy sources in order, for example, to hold parts, protect information, light interiors, etc. In this case, special steps must be taken to ensure operator safety.

41. Operator intervention

Machinery must be so designed, constructed and equipped that the need for operator intervention is limited. If operator intervention cannot be avoided, it must be possible to carry it out easily and safely.

42. Cleaning of internal parts

The machinery must be designed and constructed in such a way that it is possible to clean internal parts which have contained dangerous substances or preparations without entering them; any necessary unblocking must also be possible from the outside. If it is absolutely impossible to avoid entering the machinery, the manufacturer must take steps during its construction to allow cleaning to take place with a minimum of danger.

Sub-section 7 Indicators

43. Information devices

43.1 The information needed to control machinery must be unambiguous and easily understood.

43.2 It must not be excessive to the extent of overloading the operator.

43.3 Where the health and safety of exposed persons may be endangered by a fault in the operation of unsupervised machinery, the machinery must be equipped to give an appropriate acoustic or light signal as a warning.

44. Warning devices

44.1 Where machinery is equipped with warning devices (such as signals, etc), these must be unambiguous and easily perceived.

44.2 The operator must have facilities to check the operation of such warning devices at all times. The requirements of the specific relevant standards concerning colours and safety signals must be complied with.

45. Warning of residual risks

45.1 Where risks remain despite all the measures adopted or in the case of potential risks which are not evident (e.g. electrical cabinets, radioactive sources, bleeding of a hydraulic circuit, hazard in an unseen area, etc), the manufacturer must provide warnings.

45.2 Such warnings should preferably use readily understandable pictograms and/or be drawn up in one of the languages of the country in which the machinery is to be used, accompanied, on request, by the languages understood by the operators.

46. Marking

46.1 All machinery must be marked legibly and indelibly with the following minimum particulars.

(1) Name and address of the manufacturer.
(2) The year of construction.
(3) Name and designation of series or type.
(4) Serial number
(5) Necessary matters, if any.

46.2 Furthermore, where the manufacturer constructs machinery intended for use in a potentially explosive atmosphere, this must be indicated on the machinery.

46.3 Machinery must also bear full information relevant to its type and essential to its safe use (e.g. maximum speed of certain rotating parts, maximum diameter of tools to be fitted, and weight, etc).

46.4 Where a machine part must be handled during use with lifting equipment, its mass must be indicated legibly, indelibly and unambiguously.

47. Instructions

47.1 All machinery must be accompanied by instructions including as a minimum the following information.

(1) The information with which the machinery is marked, except the serial number, together with any appropriate additional information to facilitate maintenance.
(2) Foreseen use of the machinery within the meaning of 1.3.
(3) Work station(s) likely to be occupied by operators; this can be a drawing showing operator positions.
(4) Instructions for safety.
(5) Instructions for use.
(6) Handling, giving the mass of the machinery and in various parts where they are regularly to be transported separately.
(7) Assembly, dismantling.
(8) Adjustment.
(9) Maintenance (servicing and repair).
(10) Training instructions, where necessary.
(11) The essential characteristics of tools which may be fitted to the machinery, where necessary.
(12) The instructions should draw attention to ways in which the machinery should not be used, where necessary.

47.2 The instructions must contain the drawings and diagrams necessary for use, maintenance, inspection, checking of correct operation and, where appropriate, repair of the machinery, and all useful instructions in particular with regard to safety.
47.3 Any literature describing the machinery must not contradict to the instructions as regards safety aspects. The technical documentation describing the machinery must give information regarding the airborne noise emissions referred to in paragraph 5 and, in the case of hand-held and or hand-guided machinery, information regarding vibration.

47.4 Where necessary, the instructions must give the requirements relating to installation and

assembly for reducing noise or vibration (e.g. use of dampers, type and weight of foundation block, etc).

47.5 The instructions must give the following information concerning airborne noise emissions made by the machinery. Either the actual value or a value established on the basis of measurements made on identical machinery.

(1) Equivalent continuous A sound pressure level at work stations, where this exceeds 70 dB(A); where this level does not exceed 70 dB(A), this fact must be indicated.
(2) Peak Cinstantaneous sound pressure value at work stations, where this exceeds 63 Pa (20 Pa is equal to 130 dB(C)).
(3) Sound power level emitted by the machinery where the equivalent continuous A sound pressure level at work stations exceeds 85 dB(A).

47.6 In the case of very large machinery, instead of the sound power level in provision 2 in paragraph 5, the equivalent continuous sound pressure levels at specified positions around the machinery may be indicated.

47.7 The manufacturer must indicate the operating conditions of the machinery during measurement and what methods have been used for the measurement according to the paragraph 5. Where the work station(s) are undefined or cannot be defined, sound pressure levels must be measured at a distance of 1 metre from the surface of the machinery and at height of 1.60 metes from the floor or access platform. The position and value of the maximum sound pressure must be indicated.

47.8 If the manufacturer foresees that the machinery will be used in a potentially explosive atmosphere, the instructions must give all the necessary information.

47.9 In the case of machinery which may also be intended for use by nonfessional operators, the wording and layout of the instructions for use, whilst respecting the other essential requirements mentioned above, must take into account the level of general education and caution that can reasonably be expected from such operators.

Section 2 ADDITIONAL REQUIREMENTS FOR CERTAIN CATEGORIES OF MACHINERY

48. A gri-foodstuffs machinery

48.1 In addition to the essential health and safety requirements set out in section 1 above, where machinery is intended to prepare and process foodstuffs (e.g. cooking, refrigeration, washing, handling, packaging, storage, transport or distribution), it must be so designed and constructed as to avoid any risk of infection, sickness or contagion and the following hygiene rules must be observed.

(1) Materials in contact, or intended to come into contact, with the foodstuffs must satisfy the conditions set out in the relevant legislations. The machinery must be so designed and constructed that these materials can be cleaned before each use.
(2) All surfaces including their joining must be smooth, and must have neither ridges nor crevices which could harbour organic materials.
(3) Assemblies must be designed in such a way as to reduce projections, edges and recesses to a minimum. (They should preferably be made by welding or continuous bonding. Screws, screw heads and rivets may not be used except where technically unavoidable.)
(4) All surfaces in contact with foodstuffs must be easily cleaned and disinfected, where possible after removing easily dismantled parts. The inside surfaces must have curves of a radius sufficient to allow thorough cleaning.
(5) Liquid deriving from foodstuffs as well as cleaning, disinfecting and rinsing fluids should be able to be easily discharged from the machine.
(6) Machinery must be so designed and constructed as to prevent any liquids or living creatures, in particular the entering of insects or any organic matter accumulating in areas that cannot be cleaned.
(7) Machinery must be so designed and constructed that no ancillary substances (e.g. lubricants, etc.) can come into contact with foodstuffs. Where necessary machinery must be designed and constructed so that continuing compliance with this requirement can be checked.

48.2 The instructions must indicate the recommended products and methods for cleaning, disinfecting and rinsing (not only for easily accessible areas but also where areas to which access is impossible or unadvisable, such as piping, have to be cleaned in situ).

49. Portable hand-held and/or hand-guided machinery

49.1 In addition to the essential health and safety requirements set out in section 1 above, portable hand-held and or hand-guided machinery must conform to the following essential health and safety requirements.

(1) According to the type of machinery, it must have a supporting surface of sufficient size and have a sufficient number of handles and supports of an appropriate size and arranged to ensure the stability of the machinery under the operating conditions foreseen by the manufacturer.
(2) Except where technically impossible or where there is an independent control, in the case of handles which cannot be released in complete safety, it must be fitted with start and stop controls arranged in such a way that the operator can utilize them without releasing the handles.
(3) It must be designed, constructed or equipped to eliminate the risks of accidental starting and/or continued operation after the operator has released the handles. Equivalent steps must be taken if this requirement is not technically feasible.
(4) Portable hand-held machinery must be designed and constructed to allow, where necessary, a visual check of the contact of the tool with the material being processed.

49.2 The instructions must give the information concerning vibrations transmitted by hand-held and hand-guided machinery the weighted root mean square acceleration value to which the arms are subjected, if it exceeds 2.5 m/s2as determined by the appropriate test code. Where the acceleration does not exceed 2.5 m/s2, this must be mentioned. If there is no applicable test code, the manufacturer must indicate the measurement methods and conditions under which measurements were made.

50. Machinery for working wood and analogous materials

In addition to the essential and safety requirements set out in section 1 above, machinery for working wood and machinery for working materials with physical and technological characteristics similar to those of wood, such as cork, bone, hardened rubber, hardened plastic material and other similar stiff material must conform to the following essential health and safety requirements.

(1) The machinery must be designed, constructed or equipped so that the piece being machined can be placed and guided in safety; where the piece is hand-held on a work-bench the latter must be sufficiently stable during the work and must not impede the movement of the piece.
(2) Where the machinery is likely to be used in conditions involving the risk of wood piece ejection, it must be designed, constructed or equipped to eliminate this ejection, or, if this is not the case, so that the ejection does not engender risks for the operator and/or exposed persons.
(3) The machinery must be equipped with an automatic brake that stops the tool in a short time if there is a risk of contact with the tool whilst it runs down.
(4) Where the tool is incorporated into a non-fully automated machine, the latter must be so designed and constructed as to eliminate or reduce the risk of serious accidental injury, for example by using cylindrical cutter blocks, restricting depth of cut, etc.

Section 3 ADDITIONAL REQUIREMENTS FOR THE MOBILITY OF MACHINERY

Sub-section 1 General Provisions

51. Safety of movable machinery

51.1 If intended by the manufacturer to be used in dark places, self propelled machinery must be fitted with a lighting device appropriate to the work to be carried out, without prejudice to any other regulations applicable (road traffic regulations, navigation rules, etc).

51.2 During the handling of the machine and/or its parts there must be no possibility of sudden movements or of hazards due to instability as long as the machine and/or its parts are handled in accordance with instruction.

Sub-section 2 Work stations

52. Driving position

52.1 The driving position or location must comply with the following requirements.

(1) It must be designed with due regard to ergonomic principles.
(2) There may be two or more driving positions and, in such cases, each driving position must be provided with all the requisite controls.
(3) Where there is more than one driving position, the machinery must be designed so that the use of one of them precludes the use of the others, except in emergency stops.
(4) Visibility from the driving position must be such that the driver can, operate the machinery and its tools in their intended conditions of use in complete safety and any the exposed persons.
(5) Where necessary, appropriate devices must be provided to remedy hazards due to inadequate direct vision.

52.2 Machinery must be so designed and constructed that, from the driving position, there can be no risk to the driver and operators on board from inadvertent contact with the wheels or tracks.

52.3 The driving position must be designed and constructed so as to avoid any health risk due to exhaust gases and/or lack of oxygen.

52.4 The driving position of ride on drivers must be so designed and constructed that a

driver's cab may be fitted as long as there is room. In that case, the cab must incorporate a place for the instructions needed for the driver and/or operators. The driving position must be fitted with an adequate cab where there is a hazard due to a dangerous environment.

52.5 Where the machinery is fitted with a cab, this must be designed, constructed and/or equipped to ensure that the driver has good operating conditions and is protected against any hazards that might exist (for instance: inadequate heating and ventilation, inadequate visibility, excessive noise and vibration, falling objects, penetration by objects, rolling over, etc). The exit must allow rapid evacuation. Moreover, an emergency exit must be provided in a direction where is different from the usual exit.

52.6 The materials used for the cab and its fittings must be fire

53. Seating

The driving seat of any machinery must fulfil the following requirements.

(1) The driving seat of any machinery must enable the driver to maintain a stable position and be designed with due regard to ergonomic principles.
(2) The seat must be designed to reduce vibrations transmitted to the driver to the lowest level that can be reasonably achieved.
(3) The seat mountings must withstand all stresses to which they may be subjected, notably in the event of roll over.
(4) Where there is no floor beneath the driver's feet, the driver must have footrests covered with a slip material.
(5) Where machinery is fitted with provision for a roll over protection structure, the seat must be equipped with a safety belt or equivalent device which keeps the driver in his seat without restricting any movements necessary for driving or any movements caused by the suspension.

54. Other places

54.1 If the conditions of use provide that operators other than the driver are occasionally or regularly transported by the machinery, or work on it, appropriate places must be provided which enable them to be transported or to work on it without risk particularly the risk of falling.

54.2 Where the working conditions so permit, these work places must be equipped with seats.

54.3 Should the driving position have to be fitted with a cab, any other positions must also be protected against the hazards that justified the protection of the driving position in Article 54.

Sub-section 3 Controls

55. Control devices

55.1 The driver must be able to actuate all control devices required to operate the machinery from the driving position, except for functions which can be safely activated only by using control devices located away from the driving position.

55.2 Where there are pedals they must be so designed, constructed and fitted to allow operation by the driver in safety with the minimum risk of confusion, and they must have a slip surface and be easy to clean.

55.3 Where their operation can lead to hazards, notably dangerous movements, the machinery's controls, except for those with preset positions, must return to the neutral position as soon as they are released by the operator.

55.4 In the case of wheeled machinery, the steering system must be designed and constructed to reduce the force of sudden movements of the steering lever caused by shocks to the guide wheels.

55.5 Control systems having locking function with the differential must be so designed and arranged that it allows the differential to be unlocked when the machinery is moving.

55.6 Where the machinery is moving, 6.5 does not apply to the mobility function.

56. Starting/moving

56.1 Self-propelled machinery with a ride driver must be so equipped as to inhibit unauthorised persons from starting the engine. Travel movements of self machinery with a ride driver must be possible only if the driver is at the controls.

56.2 Where, for operating purposes, machinery must be fitted with devices which exceed its normal clearance zone (e.g. stabilizers, jib, etc), the driver must be provided with the means of checking easily, before moving the machinery, that such devices are in a position which allows safe movement.

56.3 It must not be possible for movement of the machinery to occur while the engine is being started.

57. Travelling function

57.1 Without prejudice to the provisions of road traffic regulations, self propelled machinery

and their trailers must meet the requirements for slowing, stopping, braking and immobilisation so as to ensure safety under all the operating, loading, speed, ground and gradient conditions allowed for by the manufacturer and corresponding to conditions encountered in normal use.

57.2 The driver must be able to slow down and stop self machinery by means of a main device. Where safety so requires in the event of a failure of the main device, or in the absence of the energy supply to actuate the main device, an emergency device with fully independent and easily accessible controls must be provided for slowing down and stopping.

57.3 Where safety so requires, a parking device must be provided to render stationary machinery immobile. This device may be combined with one of the devices referred to in 57.2, provided that it is purely mechanical.

57.4 Remote-controlled machinery must be designed and constructed to stop automatically if the driver loses control.

57.5 The clause 8 does not apply to the travelling function of self-propelled machinery.

58. Movement of pedestrian-controlled machinery

58.1 Movement of pedestrian-controlled self-propelled machinery must be possible only through sustained action on the relevant control by the driver. In particular, it must not be possible for movement to occur while the engine is being started.

58.2 The control systems for pedestrian-controlled machinery must be designed to mini mise the hazards, in particular crushing and injury from rotating tools, arising from inadvertent movement of the machine towards the driver. Also, the speed of normal travel of the machine must be compatible with the pace of a driver on foot.

58.3 In the case of machinery on which a rotary tool may be fitted, it must not be possible to actuate that tool when the reversing control is engaged, except where movement of the machinery results from movement of the tool. In the latter case, the reversing speed must be such that it does not endanger the driver.

59. Control circuit failure

A failure in the power supply to the power-assisted steering, where fitted, must not prevent machinery from being steered during the time required to stop it.

Sub-section 4 Protection against mechanical hazards

60. Uncontrolled movements

60.1 When a part of a machine has been stopped, any drift away from the stopping position, for whatever reason other than action at the controls, must be such that it is not a hazard to exposed persons.

60.2 Machinery must be so designed, constructed and where appropriate placed on its mobile support as to ensure that when moved the uncontrolled oscillations of its centre of gravity do not affect its stability or exert excessive strain on its structure.

61. Risk of break-up during operation

Parts of machinery rotating at high speed which, despite the measures taken, may break up or disintegrate, must be mounted and guarded in such a way that, in case of breakage, their fragments will be contained or, if that is not possible, cannot be projected towards the driving and/or operation positions.

62. Roll over

62.1 Where, in the case of self machinery with a ride driver and possibly ride-on operators, there is a risk of rolling over, the machinery must be designed for and be fitted with anchorage points allowing it to be equipped with a roll over protective structure (ROPS).

62.2 This structure must be such that in case of rolling over it affords the ride-on driver and where appropriate the ride-on operators an adequate deflection volume (DLV).

63. Falling objects

63.1 Where, in the case of machinery with a ride-on driver and possibly ride-on operators, there is a risk due to falling objects or material, the machinery should be designed for, and fitted with if its size allows anchorage points allowing it to be equipped with a fall in-object protective structure (FOPS).

63.2 This structure must be such that in the case of falling objects or material, it guarantees the ride operators an adequate deflection volume (DLV).

64. Means of access

Handholds and steps must be designed, constructed and arranged in such a way that the operators use them instinctively and do not use the controls for that purpose.

65. Towing devices

All machinery used to tow or to be towed must be fitted with towing or coupling devices designed, constructed and arranged to ensure easy and safe connection and disconnection, and to prevent accidental disconnection during use.

66. Transmission of power between self-propelled machinery (or tractor) and recipient machinery

66.1 Transmission shafts with universal joints linking self-propelled machinery (or tractor) to the first fixed bearing of recipient machinery must be guarded on the side of the self-propelled machinery and the side of the recipient machinery over the whole length of the shaft and associated universal joints.

66.2 Torque limiters or free wheels may be fitted to universal joint transmissions only on the side adjoining the driven machine. The universal transmission shaft must be marked accordingly.

66.3 The outside parts of the guard must be so designed, constructed and arranged such that they cannot turn with the transmission shaft. The guard must cover the transmission shaft to the ends of the inner jaws in the case of simple universal joints and at least to the centre of the outer joint or joints in the case of wide universal joints.

66.4 Manufacturers providing means of access to working positions near to the universal joint transmission shaft must ensure that shaft guards as described in the sixth paragraph cannot be used as steps unless designed and constructed for that purpose.

Sub-section 5 Protection against other hazards

67. Batteries

67.1 The battery housing must be constructed and located and the battery installed so as to avoid as far as possible the chance of electrolyte being ejected on to the operator in the event of roll over and/or to avoid the accumulation of vapours in places occupied by operators.

67.2 Machinery must be so designed and constructed that the battery can be disconnected with the aid of an easily accessible device provided for that purpose.

68. Fire

Depending on the hazards anticipated by the manufacturer when in use, machinery must,

where its size permits either allow easily accessible fire extinguishers to be fitted or be provided with built-in extinguisher systems.

69. Emissions of dust, gases, etc.

Where such hazards exist, the containment equipment provided for in Article 38 may be replaced by other means, for example precipitation by the spraying of water. The second and third paragraph of 35 does not apply where the main function of the machinery is the spraying of products.

Sub-section 6 Indications

70. Signs and warning

70.1 Machinery must have a means of signalling and/or instruction plates concerning use, adjustment and maintenance, wherever necessary, to ensure the health and safety of exposed persons. They must be chosen, designed and constructed in such a way as to be clearly visible and indelible.

70.2 Without prejudice to the requirements to be observed for travelling on the public highway, machinery with a ride-on driver must have the following devices.

(1) An acoustic warning device to alert exposed persons.
(2) A system of light signals relevant to the intended conditions of use such as stop lamps, reversing lamps and rotating beacons. This requirement does not apply to machinery intended solely for underground working and having no electrical power.

70.3 Remote-controlled machinery which under normal conditions of use exposes persons to the hazards of impact or crushing must be fitted with appropriate means to signal its movements or with means to protect exposed persons against such hazards. The same applies to machinery which involves, when in use, the constant repetition of a forward and backward movement on a single axis where the back of the machine is not directly visible to the driver.

70.4 Machinery must be so constructed that all warning and signalling devices cannot be disabled unintentionally. Where this is essential for safety, such devices must be provided with the means to check that they are in good working order and their failure must be made apparent to the operator.

70.5 Where the movement of machinery or its tools is particularly hazardous, signs on the machinery must be provided to warn against approaching the machinery while it is working; the signs must be legible at a sufficient distance to ensure the safety of persons who are in the

vicinity.

71. Marking

In addition to the minimum requirements set out in Article 49, the following information must be marked on the machinery.

(1) Nominal power expressed in kW.
(2) Mass in kg of the most usual configuration and, where appropriate.
(3) Maximum drawbar pull provided for by the manufacturer at the coupling hook, in N.
(4) Maximum vertical load provided for by the manufacturer on the coupling hook, in N.

72. Instruction handbook

Apart from the minimum requirements set out in Article50, the instruction handbook must contain the following information.

(1) Regarding the vibrations emitted by the machinery, either the actual value or a figure calculated from measurements performed on identical machinery. The weighted root mean square acceleration value to which the arms are subjected, if it exceeds 2.5 m/s2, should it not exceed 2.5 m/s2, this must be mentioned. The weighted root mean square acceleration value to which the body (feet or posterior) is subjected, if it exceeds 0.5 m/s2, or should it not exceed 0.5 m/s2, this must be mentioned(The manufacturer must indicate the operating conditions of the machinery during measurement and which methods were used for taking the measurements)
(2) In the case of machinery allowing several uses depending on the equipment used, manufacturers of basic machinery to which interchangeable equipment may be attached and manufacturers of the interchangeable equipment must provide the necessary information to enable the equipment to be fitted and used safely.

Section 4 ADDITIONAL REQUIREMENTS FOR A LIFTING OPERATION

73. Scope

73.1 Machinery presenting hazards due to lifting operations-mainly hazards of load falls and collisions or hazards of tipping caused by a lifting operation-must be designed and constructed to meet the requirements of section 2 and section 3.

73.2 Risks due to a lifting operation exist particularly in the case of machinery designed to move a unit load involving a change in level during the movement. The load may consist of objects, materials or goods.

Sub-section 1 General provisions

74. Definitions

The definitions of the terminology used in this section are as follows;

(1) "Lifting accessories" mean components or equipment not attached to the machine and placed between the machinery and the load or on the load in order to attach it.
(2) "Separate lifting accessories" mean accessories which help to make up or use a slinging device, such as eye hooks, shackles, rings, eye bolts, etc.
(3) "Guided load" means the load where total movement is made along rigid or flexible guides, whose position is determined by fixed points.
(4) "Working coefficient" means the arithmetic ratio between the load guaranteed by the manufacturer up to which a piece of equipment, and an accessory or machinery is able to hold it and the maximum working load marked on the equipment, accessory or machinery respectively.
(5) "Test coefficient" means the arithmetic ratio between the load used to carry out the static or dynamic tests on a piece of equipment, an accessory or machinery and the maximum working load marked on the piece of equipment, accessory or machinery.
(6) "Static test" means the test during which the machinery or the lifting accessory is first inspected and then subjected to a force corresponding to the maximum working load multiplied by the appropriate static test coefficient and then re-inspected once the said load has been released to ensure no damage has occurred.
(7) "Dynamic test" means the test during which the machinery is operated in all its possible configurations at maximum working load with account being taken of the dynamic behaviour of the machinery in order to check that the machinery and safety features are functioning properly.

75. Protection against mechanical hazards

75.1 Machinery must be so designed and constructed that the stability required in 13 is maintained both in service and out of service, including all stages of transportation, assembly and dismantling, during foreseeable component failures and also during the tests carried out in accordance with the instruction handbook.

75.2 To that end, machinery must be provided with devices which act on the guide rails or tracks to prevent derailment. However, if derailment occurs despite such devices, or if there is a failure of a rail or a running component, devices must be provided which prevent the equipment, component or load from falling or the machine overturning.

75.3 Mechanical strength shall comply with the following requirements.
(1) Machinery, lifting accessories and removable components must be capable of

withstanding the stresses to which they are subjected, both in and, where applicable, out of use, under the installation and operating conditions provided for by the manufacturer, and in all relevant configurations, with due regard, where appropriate, to the effects of atmospheric factors and forces exerted by persons(This requirement must also be satisfied during transport, assembly and dismantling).

(2) Machinery and lifting accessories must be designed and constructed so as to prevent failure from fatigue or wear, taking due account of their intended use.

(3) The materials used must be chosen on the basis of the working environments provided for by the manufacturer, with special reference to corrosion, abrasion, impacts, cold brittleness and ageing.

(4) The machinery and the lifting accessories must be designed and constructed to withstand overload in static tests without permanent deformation or patent defect. The calculation must take account of the values of the static test coefficient chosen to guarantee an adequate level of safety. That coefficient is1.5, as a general rule, in case of manually machinery and lifting accessories, and 1.25 in case of other machinery.

(5) Machinery must be designed and constructed to undergo, without failure, the dynamic tests carried out using the maximum working load multiplied by the dynamic test coefficient. This dynamic test coefficient is chosen so as to guarantee an adequate level of safety: the coefficient is, as a general rule, equal to 1.1.

(6) The dynamic tests must be performed on machinery ready to be put into service under normal conditions of use. As a general rule, the tests will be performed at the nominal speeds laid down by the manufacturer. Should the control circuit of the machinery allow for a number of simultaneous movements (for example, rotation and displacement of the load), the tests must be carried out under the least favourable conditions, i.e. as a general rule by combining the movements concerned.

76. Pulleys, etc.

Pulleys, drums and wheels or ropes must satisfy the following requirements.

(1) Pulleys, drums and wheels must have a diameter commensurate with the size of rope or chains with which they can be fitted.

(2) Drums and wheels must be so designed, constructed and installed so that the ropes or chains with which they are equipped can normally run without falling off.

(3) Ropes used directly for lifting or supporting the load must not include any splicing other than at their ends (splicings are tolerated in installations which are intended from their design to be modified regularly according to needs for use). Complete ropes and their endings have a working coefficient chosen so as to guarantee an adequate level of safety; as a general rule, this coefficient is equal to 5.

(4) Lifting chains have a working coefficient chosen so as to guarantee an adequate level of safety; as a general rule, this coefficient is equal to 4.

(5) In order to verify that an adequate working coefficient has been attained, the manufacturer or his authorized representative established within the Community must, for each type of chain and rope used directly for lifting the load, and for the rope ends, perform the appropriate tests or have such tests performed.

77. Separate lifting accessories

Lifting accessories must be sized with due regard to fatigue and ageing processes for a number of operating cycles consistent with their expected life as specified in the operating conditions for a given application, and must fulfil the following requirements.

(1) The working coefficient of the metallic rope/rope combination is chosen so as to guarantee an adequate level of safety; this coefficient is, as a general rule, more than 5.
(2) Ropes must not comprise any splices or loops other than at their ends.
(3) Where chains with welded links are used, they must be of the short link type. The working coefficient of chains of any type is chosen so as to guarantee an adequate level of safety; this coefficient is, as a general rule, more than 4.
(4) The working coefficient for textile ropes or slings is dependent on the material, method of manufacture, dimensions and use. This coefficient is chosen so as to guarantee an adequate level of safety; it is, as a general rule, more than 7, provided the materials used are shown to be of very good quality and the method of manufacture is appropriate to the intended use. Should this not be the case, the coefficient is, as a general rule, set at a higher level in order to secure an equivalent level of safety. Textile ropes and slings must not include any knots, connections or splicing other than at the ends of the sling, except in the case of an endless sling.
(5) All metallic components making up, or used with a sling must have a working coefficient chosen as to guarantee an adequate level of safety; this coefficient is, as a general rule, more than 4.
(6) The maximum working capacity of a multi legged sling is determined on the basis of the safety coefficient of the weakest leg, the number of legs and a reduction factor which depends on the slinging configuration.
(7) In order to verify that an adequate working coefficient has been attained, the manufacturer must, for each type of component referred to in paragraph 1 to 5 perform the appropriate tests or have such tests performed.

78. Control of movements

Devices for controlling movements must act in such a way that the machinery on which they are installed is kept safe:

(1) Machinery must be so designed or fitted with devices that the amplitude of movement of

its components is kept within the specified limits. Warning sings shall be provided in appropriated positions.

(2) Where collision hazards exists during operation, due to several machines in the same line, a collision prevention device shall be provided.

(3) The mechanisms of machinery must be so designed and constructed that the loads cannot creep dangerously or fall freely and unexpectedly, even in the event of partial or total failure of the power supply or when the operator stops operating the machine.

(4) It must not be possible, under normal operating conditions, to lower the load solely by friction brake, except in the case of machinery, whose function requires it to operate in that way.

(5) It must be so designed and constructed that inadvertent dropping of the loads is avoided.

79. Handling of loads

79.1 The driving position of machinery must be located in such a way as to ensure that widest possible view of trajectories of the moving parts, in order to avoid possible collisions with persons or equipment or other machinery which might be maneuvering at the same time and liable to constitute a hazard.

79.2 Machinery with guided loads fixed in one place must be designed and constructed so as to prevent exposed persons from being hit by the load or counter-weights.

80. Lightning

Machinery in need of protection against the effects of lightning while being used must be fitted with a system for conducting the resultant electrical charges to earth.

Sub-section 2 Special requirements for machinery whose power source is other than manual effort

81. Controls

81.1 The requirements laid down in 52, 53.1 and 53.2 and 54 also apply to non-mobile machinery.

81.2 The devices controlling movements of the machinery or its equipment must return to their neutral position as soon as the operator releases them. However, for partial or complete movements in which there is no risk of the load or the machinery colliding, the said devices may be replaced by controls authorizing automatic stops at pre-selected levels without utilizing a hold-to-run control device.

81.3 Machinery with a maximum working load of not less than 1000 kilograms or an overturning moment of not less than 40,000Nm must be fitted with devices to warn the driver and prevent dangerous movements of the load in the following events.

(1) Machinery under overloads
(2) The occurrence of moment due to the excess of working loads or overloads
(3) The occurrence of overturning moment due to overloads

81.4 Cable carriers, tractors or tractor carriers must be held by counterwork by a device allowing permanent control of the tension.

83. Risks to exposed persons

Machinery with guided loads and machinery whose load supports follow a clearly defined path must be equipped with devices to prevent any risks to exposed persons.

83. Fitness of purposes

When machinery is placed on the market or is first put into service, the manufacturer or his authorized representative must ensure, by taking appropriate measures or having them taken, that lifting accessories and machinery which are ready for use-whether manually or power-operated-can fulfil their specified functions safely.

Sub-section 3 Marking

84. Chains and ropes

Each length of lifting chain, rope or webbing not forming part of an assembly must bear a mark or, where this is not possible, a plate or irremovable ring bearing the name and address of the manufacturer and the identifying reference of the relevant certificate. The certificate should show at least the following information.

(1) Nominal size.
(2) Structure.
(3) Used material.
(4) Any special metallurgical treatment applied to the material.
(5) Test standard .
(6) A maximum working load of chain or rope. A range of values may be given for specified applications.

85. Lifting accessories

85.1 The following information shall be marked on lifting accessories.

(1) Identification of the manufacturer.
(2) Identification of the material (e.g. international classification) where this information is needed for dimensional compatibility.
(3) Identification of the maximum working load.

85.2 In the case of accessories including components such as cables or ropes, on which marking is physically impossible, the particulars referred to in the first paragraph must be displayed on a plate or by some other means and securely affixed to the accessory.

85.3 The particulars must be legible and located in a place where they are not liable to disappear as a result of machining, wear, etc, or jeopardies the strength of the accessory.

86. Machinery

86.1 In addition to the minimum information provided for in 46, each machine must bear the information in the following manner legibly and indelibly, to identify the nominal load.

(1) Displayed in uncoded form and prominently on the equipment in the case of machinery which has only one possible value.
(2) Where the nominal load depends on the configuration of the machine, each driving position must be provided with a load plate indicating, preferably in diagrammatic form or by means of tables, the nominal loads for each configuration.

86.2 Machinery equipped with a load elevating system which allows persons access to and involves a risk of falling must have a clear and indelible warning indications prohibiting the boarding of persons. This warning must be visible at each place where access is possible.

Sub-section 4 Instruction handbook

87. Lifting accessories

Each lifting accessory or each commercially indivisible batch of lifting accessories must be accompanied with an instruction handbook setting out at least the following particulars.

(1) Normal conditions of use.
(2) Instructions for use, assembly and maintenance.

(3) The limits of use (particularly for the accessories which cannot comply with 78.

88. Machinery

In addition to Article 50, the instruction handbook must include the following information.

(1) The technical characteristics of the machinery, and in particular, where appropriate, a copy of the load table described in Number 2 of paragraph 1 of Article 89, the reactions at the supports or anchors and characteristics of the tracks, and, where appropriate, the definition and the means of installation of the ballast.
(2) The contents of the logbook(if it is not supplied with the machinery).
(3) Advice for use, particularly to offset the lack of direct sight of the load by the operator.
(4) The necessary instructions for performing the tests before first putting into service machinery which is not assembled on the manufacturer's premises in the form in which it is to be used.

Section 5 REQUIREMENTS FOR ELEVATORS

Sub-section 1 General provisions

89. Definition

For the purposes of this Chapter, 'carrier' means the device by which persons are supported in order to be lifted, lowered or moved.

90. Mechanical strength

90.1 The working coefficients defined in Article 78 and Article 79 are inadequate for machinery intended for the lifting or moving of persons and must, as a general rule, be doubled.

90.2 The floor of the carrier must be designed and constructed to offer the space and strength corresponding to the maximum number of persons and the maximum working load set by the manufacturer.

91. Loading control

The requirements of 81 apply regardless of the maximum working load figure. This requirement does not apply to machinery in respect of which the manufacturer can demonstrate that there is no risk of overloading and/or overturning.

Sub-section 2 Controls

92. Control devices

92.1 The carrier must, as a general rule, be designed and constructed so that persons inside have means of controlling movements upwards and downwards, and if appropriate, of moving the carrier horizontally in relation to the machinery.

92.2 In operation, those controls must override the other devices controlling the same movement, with the exception of the emergency stop devices.

93.3 The controls for these movements must be of the maintained command type, except in the case of machinery serving specific levels.

93. Safety during operation

If machinery for the lifting or moving of persons can be moved with the carrier in a position other than the rest position, it must be designed and constructed so that the person or persons in the carrier have the means of preventing hazards produced by the movement of the machinery.

94. Prevention of overspeed

Machinery for the lifting or moving of persons must be designed, constructed or equipped so that excess speeds of the carrier do not cause hazards.

95. Risks of persons falling from the carrier

95.1 If the measures referred to in 37 are not adequate, carriers must be fitted with a sufficient number of anchorage points for the number of persons possibly using the carrier, strong enough for the attachment of personal protective equipment against the danger of falling.

95.2 Any trap-doors in floors or ceilings or side doors must open in a direction which obviates any risk of falling should they open unexpectedly.

95.3 Machinery for lifting or moving must be designed and constructed to ensure that the floor of the carrier does not tilt to an extent which creates a risk of the occupants falling, including when moving. The floor of the carrier must be slip-resistant.

96. Risks of the carrier falling or overturning

96.1 Machinery for the lifting or moving of persons must be designed and constructed to prevent the carrier falling or overturning.

96.2 Acceleration and braking of the carrier or carrying vehicle, under the control of the operator or triggered by a safety device and under the maximum load and speed conditions laid down by the manufacturer, must not cause any danger to exposed persons.

97. Markings

Where necessary to ensure safety, the carrier must bear the relevant essential information.

Chapter 2 Essential Safety Certification Requirements for Personal Protective Equipment(hereinafter "PPE") (S1-P-36-2003)

98. This requirement apply to the portable equipment, the emergency equipment, portable device.

99. Classification of PPE

99.1 PPE for the protection of simple hazards

(1) mechanical action whose effects are superficial (gardening gloves, thimbles, etc.)
(2) cleaning materials of weak action and easily reversible effects (gloves affording protection against diluted detergent solutions, etc.)
(3) risks encountered in the handling of hot components which do not expose the user to a temperature exceeding 50°C or to dangerous impacts (gloves, aprons for professional use, etc.)
(4) atmospheric agents of a neither exceptional nor extreme nature (headgear, seasonal clothing, footwear, etc.)
(5) minor impacts and vibrations which do not affect vital areas of the body and whose effects cannot cause irreversible lesions (light anti-scalping helmets, gloves, light footwear, etc.)
(6) sunlight (sunglasses)

99.2 PPE for the protection of high hazards

(1) filtering respiratory devices for protection against solid and liquid aerosols or irritant, dangerous, toxic or radio toxic gases
(2) respiratory protection devices providing full insulation from the atmosphere, including those for use in diving
(3) PPE providing only limited protection against chemical attack or against ionizing radiation
(4) emergency equipment for use in high-temperature environments the effects of which are

comparable to those of an air temperature of 100°C or more and which may or may not be characterized by the presence of infra-red radiation, flames or the projection of large amounts of molten material

(5) emergency equipment for use in low-temperature environments the effects of which are comparable to those of an air temperature of 50°C or less
(6) PPE to protect against falls from a height
(7) PPE against electrical risks and dangerous voltages or that used as insulation in high-tension work
(8) motor cycle helmets and visors

100. Exclusion of application

(1) PPE designed and manufactured specifically for use by the armed forces or in the maintenance of law and order (helmets, shields, etc.)
(2) PPE for self-defence (aerosol canisters, personal deterrent weapons, etc.)
(3) PPE designed and manufactured for private use against
   A. adverse atmospheric conditions (headgear, seasonal clothing, footwear, umbrellas, etc.),
   B. damp and water (dish-washing gloves, etc.),
   C. heat (gloves etc.).
(4) PPE intended for the protection or rescue of persons on vessels or aircraft, not worn all the time.

101. General Requirements applicable to all PPE

PPE must provide adequate protection against all risks encountered.

102. Design principles

102.1 Ergonomics PPE must be so designed and manufactured that in the foreseeable conditions of use for which it is intended the user can perform the risk-related activity normally whilst enjoying appropriate protection of the highest possible level.

102.2 Levels and classes of protection

102.2.1 Highest level of protection possible The optimum level of protection to be taken into account in the design is that beyond which the constraints imposed by the wearing of the PPE would prevent its effective use during the period of exposure to the risk or normal performance of the activity.

102.2.2 Classes of protection appropriate to different levels of risk Where differing foreseeable conditions of use are such that several levels of the same risk can be

distinguished, appropriate classes of protection must be taken into account in the design of the PPE.

103. Innocuousness of PPE

103.1 Absence of risks and other 'inherent' nuisance factors PPE must be so designed and manufactured as to preclude risks and other nuisance factors under foreseeable conditions of use.

103.2 Suitable constituent materials PPE materials and parts, including any of their decomposition products, must not adversely affect user hygiene or health.

103.3 Satisfactory surface condition of all PPE parts in contact with the user Any PPE part in contact or in potential contact with the user when such equipment is worn must be free of roughness, sharp edges, projections and the like which could cause excessive irritation or injuries.

103.4 Maximum permissible user impediment Any impediment caused by PPE to movements to be made, postures to be adopted and sensory perception must be minimized nor must PPE cause movements which endanger the user or other persons.

104. Comfort and efficiency

104.1 Adaptation of PPE to user morphology PPE must be so designed and manufactured as to facilitate correct positioning on the user and to remain in place for the foreseeable period of use, bearing in mind ambient factors, movements to be made and postures to be adopted. For this purpose, it must be possible to optimize PPE adaptation to user morphology by all appropriate means, such as adequate adjustment and attachment systems or the provision of an adequate size range.

104.2 Lightness and design strength PPE must be as light as possible without prejudicing design strength and efficiency. PPE must be capable of withstanding the effects of ambient phenomena inherent under the foreseeable conditions of use.

104.3 Compatibility of different classes or types of PPE designed for simultaneous use If the same manufacturer markets several PPE models of different classes or types in order to ensure the simultaneous protection of adjacent parts of the body against combined risks, these must be compatible.

105. Information supplied by the manufacturer In addition to the name and address of the manufacturer, the notes that must be drawn up by the former and supplied when PPE is placed on the market must contain all relevant information on:

(1) storage, use, cleaning, maintenance, servicing and disinfection.
(2) performance and the levels of protection provided by the PPE in question;
(3) suitable PPE accessories and the characteristics of appropriate spare parts;
(4) the classes of protection appropriate to different levels of risk and the corresponding limits of use;
(5) the obsolescence deadline or period of obsolescence of PPE or certain of its components;
(6) the type of packaging suitable for transport;
(7) the significance of any markings

106. Additional Requirements to Common to Several classes or Types of PPE

106.1 PPE incorporating adjustment systems If PPE incorporates adjustment systems, the latter must be so designed and manufactured as not to become incorrectly adjusted without the user's knowledge under the foreseeable conditions of use.

106.2 PPE 'enclosing' the parts of the body to be protected As far as possible, PPE 'enclosing' the parts of the body to be protected must be sufficiently ventilated to limit perspiration resulting from use; if this is not the case, it must if possible be equipped with devices which absorb perspiration.

106.3 PPE for the face, eyes and respiratory tracts

(1) Any restriction of the user's field of vision or sight by PPE for the face, eyes or respiratory tract must be minimized.
(2) The degree of optical neutrality of the vision systems of these PPE classes must be compatible with the type of relatively meticulous and/or prolonged activities of the user.
(3) If necessary, they must be treated or provided with facilities to prevent moisture formation.
(4) PPE models intended for users requiring sight correction must be compatible with the wearing of spectacles or contact lenses.

106.4 PPE subject to ageing

106.4.1 If it is known that the design performances of new PPE may be significantly affected by ageing, the date of manufacture and/or, if possible, the date of obsolescence, must be indelibly inscribed on every PPE item or interchangeable component placed on the market in such a way as to preclude any misinterpretation; this information must also be indelibly inscribed on the packaging.

106.4.2 If a manufacturer is unable to give an undertaking with regard to the useful life of PPE, his notes must provide all the information necessary to enable the purchaser or user to

establish a reasonable obsolescence date, bearing in mind the quality level of the model and the effective conditions of storage, use, cleaning, servicing and maintenance.

106.4.3 Where appreciable and rapid deterioration in PPE performance is likely to be caused by ageing resulting from the periodic use of a cleaning process recommended by the manufacturer, the latter must, if possible, affix a mark to each item of PPE placed on the market indicating the maximum number of cleaning operations that may be carried out before the equipment needs to be inspected or discarded; failing that, the manufacturer must give this information in his notes.

106.5 PPE which may be caught up during use Where the foreseeable conditions of use include in particular the risk of the PPE being caught up by a moving object thereby creating a danger for the user, the PPE must possess an appropriate resistance threshold above which a constituent part will break and eliminate the danger.

106.6 PPE for use in explosive atmospheres PPE intended for use in explosive atmospheres must be so designed and manufactured that it cannot be the source of an electric, electrostatic or impact-inducedarc or spark likely to cause an explosive mixture to ignite.

106.7 PPE intended for emergency use or rapid installation and/or removal

106.7.1 These PPE classes must be so designed and manufactured as to minimize the time required for attachment and (or) removal.

106.7.2 Any integral systems permitting correct positioning on, or removal from, the user must be susceptible of rapid and easy operation.

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106.8 PPE for use in very dangerous situations

106.8.1 The information notes supplied by the manufacturer together with PPE for use in the very dangerous situations referred to in Article 8 (4) (a) must include, in particular, data intended for the exclusive use of competent trained individuals who are qualified to interpret them and ensure their application by the user.

106.8.2 They must also describe the procedure to be adopted in order to verify that PPE is correctly adjusted and functional when worn by the user.

106.8.3 If PPE incorporates an alarm which is activated in the absence of the level of protection normally provided, this must be so designed and accommodated as to be perceived by the user in the conditions of use for which the PPE is marketed.

106.9 PPE incorporating components which can be adjusted or removed by the user Any PPE

components which can be adjusted or removed by the user for the purpose of replacement must be so designed and manufactured as to facilitate adjustment, attachment and removal without tools.

106.10 PPE for connection to another, external complementary device If PPE incorporates a system permitting connection to another, complementary, device, the attachment mechanism must be so designed and manufactured as to enable it to be mounted only on appropriate equipment.

106.11 PPE incorporating a fluid circulation system If PPE incorporates a fluid circulation system, the latter must be so chosen, or designed, and incorporated as to permit adequate fluid renewal in the vicinity of the entire part of the body to be protected, irrespective of user gestures, posture or movement under the foreseeable conditions of use.

106.12 Marking of Safety Certification Mark(S Mark)

106.12.1 The identification or recognition marks directly or indirectly relating to health and safety affixed to these types or classes of PPE must remain perfectly legible throughout the foreseeable useful life of the PPE.

106.12.2 If PPE (or a PPE component) is too small to allow all or part of the necessary marking to be affixed, the relevant information must be mentioned on the packing and in the manufacturer's notes.

106.13 PPE in the form of clothing capable of signalling the user's presence visually PPE in the form of clothing intended for foreseeable conditions of use in which the user's presence must be visibly and individually signalled must have one(or more) judiciously positioned means of or devices for emitting direct or reflected visible radiation of appropriate luminous intensity and photometric and colorimetric properties.

106.14 'Multi-risk' PPE All PPE designed to protect the user against several potentially simultaneous risks must be so designed and manufactured as to satisfy, in particular, the basic requirements specific to each of those risks

107 Additional Requirements Specific to Particular Risks

107.1 Protection against impact caused by falling or projecting objects and collision Suitable PPE for this type of risk must be sufficiently shock-absorbent to prevent injury resulting, in particular, from the crushing or penetration of the protected part, at least up to an impact-energy level above which the excessive dimensions or mass of the absorbing device would preclude effective use of the PPE for the foreseeable period of wear.

107.2 Prevention of falls due to slipping The out soles for footwear designed to prevent slipping must be so designed, manufactured or equipped with added elements as to ensure satisfactory adhesion by grip and friction having regard to the nature or state of the surface.

107.3 Prevention of falls from a height

107.3.1 PPE designed to prevent falls from a height or their effects must incorporate a body harness and an attachment system which can be connected to a reliable anchorage point. It must be designed so that under the foreseeable conditions of use the vertical drop of the user is minimized to prevent collision with obstacles and the braking force does not, however, attain the threshold value at which physical injury or the tearing or rupture of any PPE component which might cause the user to fall can be expected to occur.

107.3.2 It must also ensure that after braking the user is maintained in a correct position in which he may await help if necessary.

107.3.3 The manufacturer's notes must specify in particular all relevant information relating to:

(1) the characteristics required for the reliable anchorage point and the necessary minimum clearance below the user
(2) the proper way of putting on the body harness and of connecting the attachment system to the reliable anchorage point
(3) instruction for use

107.4 Mechanical vibration

107.4.1 PPE designed to prevent the effects of mechanical vibrations must be capable of ensuring adequate attenuation of harmful vibration components for the part of the body at risk.

107.4.2 Under no circumstances must the effective value of the accelerations transmitted to the user by those vibrations exceed the limit values recommended in the light of the maximum foreseeable daily exposure of the part of the body at risk.

107.5 Protection against (static) compression of part of the body PPE designed to protect part of the body against (static) compressive stress must be sufficiently capable of attenuating its effects to prevent serious injury or chronic complaints.

107.6 Protection against physical injury (abrasion, perforation, cuts, bites) PPE constituent materials and other components designed to protect all or part of the body against superficial injury caused by machinery, such as abrasion, perforation, cuts or bites, must be so chosen or designed and incorporated as to ensure that these PPE classes provide sufficient resistance to

abrasion, perforation and gashing under the foreseeable conditions of use.

107.7 Prevention of drowning (life jackets, arm bands and lifesaving suits)

107.7.1 PPE designed to prevent drowning must be capable of returning to the surface as quickly as possible, without danger to his health, a user who may be exhausted or unconscious after falling into a liquid medium, and of keeping him afloat in a position which permits breathing while awaiting help.

107.7.2 PPE may be wholly or partially inherently buoyant or may be inflated either by gas which can be manually or automatically released or orally.

107.7.3 PPE must, without prejudice to its satisfactory operation, be capable of withstanding the effects of impact with the liquid medium and the environmental factors inherent in that medium,

107.7.4 Inflatable PPE must be capable of inflating rapidly and fully. Where particular foreseeable conditions of use so require, certain types of PPE must also satisfy one or more of the following additional requirements.

(1) it must have all the inflation devices referred to in the second subparagraph, and/or a light or sound-signalling device,
(2) it must have a device for hitching and attaching the body so that the user may be lifted out of the liquid medium,
(3) it must be suitable for prolonged use throughout the period of activity exposing the user, possibly dressed, to the risk of falling into the liquid medium or requiring his immersion in it.

107.8 Buoyancy aids

107.8.1 Clothing which will ensure an effective degree of buoyancy, depending on its foreseeable use, which is safe when worn and which affords positive support in water.

107.8.2 In foreseeable conditions of use, this PPE must not restrict the user's freedom of movement.

107.8.3 PPE must enable him, in particular, to swim or take action to escape from danger or rescue other persons.

107.9 Ear muffs or ear plugs

107.9.1 Ear muffs or ear plugs must be capable of attenuating the noise level to such an

extent that the equivalent sound levels perceived by the user do not under any circumstances exceed the allowable limit values laid down by the notification of Ministry of Labour.

107.9.2 All Ear muffs or ear plugs must bear labelling indicating the noise attenuation level and the value of the comfort index provided by the Ear muffs or ear plugs should this not be possible, the labelling must be fixed to the packaging.

107.10 Protection against heat and/or fire PPE designed to protect all or part of the body against the effects of heat and/or fire must possess thermal insulation capacity and mechanical strength appropriate to foreseeable conditions of use.

107.11 PPE constituent materials and other components

107.11.1 Constituent materials and other components suitable for protection against radiant and convective heat must possess an appropriate coefficient of transmission of incident heat flux and be sufficiently incombustible to preclude any risk of spontaneous ignition under the foreseeable conditions of use.

107.11.2 Where the outside of these materials and components must be reflective, its reflective power must be appropriate to the intensity of the heat flux due to radiation in the infra-red range.

107.11.3 Materials and other components of equipment intended for brief use in high-temperature environments and of PPE which may be splashed by hot products such as large quantities of molten material must also possess sufficient thermal capacity to retain most of the stored heat until after the user has left the danger area and removed his PPE.

107.11.4 PPE materials and other components which may be splashed by large amounts of hot products must also possess sufficient mechanical-impact absorbency (see 3.1).

107.11.5 PPE materials and other components which may accidentally come into contact with flame and those used in the manufacture of fire-fighting equipment must also possess a degree of non-flammability corresponding to the risk class associated with the foreseeable conditions of use. They must not melt when exposed to flames nor contribute to flame propagation.

107.12 Complete PPE ready for use

107.12.1 The quantity of heat transmitted by PPE to the user must be sufficiently low to prevent the heat accumulated during wear in the part of the body at risk from attaining, under any circumstances, the pain or health impairment threshold.

107.12.2 PPE must if necessary prevent liquid or steam penetration and must not cause burns

resulting from contact between its protective integument and the user.

107.12.3 If PPE incorporates refrigeration devices for the absorption of incident heat by means of liquid evaporation or solid sublimation, their design must be such that any volatile substances released are discharged beyond the outer protective integument and not towards the user.

107.12.4 If PPE incorporates a breathing device, the latter must adequately fulfil the protective function assigned to it under the foreseeable conditions of use.

107.12.5 The manufacturer's notes accompanying each PPE model intended for brief use in high-temperature environments must in particular provide all relevant data for the determination of the maximum permissible user exposure to the heat transmitted by the equipment when used in accordance with its intended purpose.

107.13 Protection against cold

107.13.1 PPE constituent materials and other components Constituent materials and other components suitable for protection against cold must possess a coefficient of transmission of incident thermal flux as low as required under the foreseeable conditions of use. Flexible materials and other components of PPE intended for use in a low-temperature environment must retain the degree of flexibility required for the necessary gestures and postures.

107.13.2 PPE materials and other components which may be splashed by large amounts of cold products must also possess sufficient mechanical-impact absorbency (see 110.1 to 110.4.2).

107.13.3 The flux transmitted by PPE to the user must be sufficiently low to prevent the cold accumulated during wear at any point on the part of the body being protected, including the tips of fingers and toes in the case of hands or feet, from attaining, under any circumstances, the pain or health-impairment threshold.

107.13.4 PPE must as far as possible prevent the penetration of such liquids as rainwater and must not cause injuries resulting from contact between its cold protective integument and the user.

107.13.5 If PPE incorporates a breathing device, this must adequately fulfil the protective function assigned to it under the foreseeable conditions of use.

107.13.6 The manufacturer's notes accompanying each PPE model intended for brief use in low-temperature environments must provide all relevant data concerning the maximum permissible user exposure to the cold transmitted by the equipment.

107.14 Protection against electric shock

107.14.1 PPE designed to protect all or part of the body against the effects of electric current must be sufficiently insulated against the voltages to which the user is likely to be exposed under the most unfavourable foreseeable conditions.

107.14.2 The constituent materials and other components of these PPE classes must be so chosen or designed and incorporated as to ensure that the leakage current measured through the protective integument under test conditions at voltages correlated with those likely to be encountered in situ is minimized and, at all events, below a maximum conventional permissible value which correlates with the tolerance threshold.

107.14.3 Together with their packaging, PPE types intended exclusively for use during work or activities in electrical installations which are or may be under tension must bear markings indicating, in particular, their protection class and (or) corresponding operating voltage, their serial number and their date of manufacture; a space must also be provided outside the protective integument of such PPE for the subsequent inscription of the date of entry into service and those of the periodic tests or inspections to be periodic tests or inspections to be conducted.

107.14.4 The manufacturer's notes must indicate, in particular, the exclusive use for which these PPE types are intended and the nature and frequency of the dielectric tests to which they are to be subjected during their useful life.

107.15 Protection of non-ionizing radiation

107.15.1 PPE designed to prevent acute or chronic eye-damage from sources of non-ionizing radiation must be capable of absorbing or reflecting the majority of the energy radiated in the harmful wavelengths without unduly affecting the transmission of the innocuous part of the visible spectrum, the perception of contrasts and the ability to distinguish colours where required by the foreseeable conditions of use.

107.15.2 Protective glasses must be so designed and manufactured as to possess, for each harmful wave, a spectral transmission factor such that the radiant-energy illumination density capable of reaching the user's eye through the filter is minimized and, under no circumstances, exceeds the maximum permissible exposure value.

107.15.3 The glasses must not deteriorate or lose their properties as a result of the effects of radiation emitted under the foreseeable conditions of use and all marketed specimens must bear the protection-factor number corresponding to the spectral distribution curve of their transmission factor.

107.15.4 Glasses suitable for radiation sources of the same type must be classified in the ascending order of their protection factors and the manufacturer's notes must indicate, in particular, the transmission curves which make it possible to select the most appropriate PPE bearing in mind such inherent factors of the effective conditions of use as distance to source and the spectral distribution of the energy radiated at that distance.

107.15.5 The relevant protection-factor number must be marked on all specimens of filtering glasses by the manufacturer.

107.16 Protection against ionizing radiation

107.16.1 Protection against external radioactive contamination

(1) PPE constituent materials and other components designed to protect all or part of the body against radioactive dust, gases, liquids or mixtures thereof must be so chosen or designed and incorporated as to ensure that this equipment effectively prevents the penetration of the contaminants under the foreseeable conditions of use.
(2) Depending on the nature or condition of these contaminants, the necessary leak-tightness can be provided by the imperme ability of the protective integument and/or by any other appropriate means, such as ventilation and pressurization systems designed to prevent the back-scattering of these contaminants.
(3) Any decontamination measures to which PPE is subject must not prejudice its possible re-use during the foreseeable useful life of these classes of equipment.

107.16.2 Limited protection against external irradiation

(1) PPE intended to provide complete user protection against external irradiation or, failing this, adequate attenuation thereof, must be designed to counter only weak electron (e.g. beta) or weak photon (e.g. X, gamma) radiation.
(2) The constituent materials and other components of these PPE classes must be so chosen or designed and incorporated as to provide the degree of user protection required by the foreseeable conditions of use without leading to an increase in exposure time as a result of the impedance of user gestures, posture or movement.
(3) PPE must bear a mark indicating the type and thickness of the constituent material(s) suitable for the foreseeable conditions of use.

107.17 Protection against dangerous substances and infective agents

107.17.1 Respiratory protection

(1) PPE intended for the protection of the respiratory tract must make it possible to supply the user with breathable air when the latter is exposed to a polluted atmosphere and/or an

atmosphere having inadequate oxygen concentration.

(2) The breathable air supplied to the user by the PPE must be obtained by appropriate means, for example after filtration of the polluted air through the protective device or appliance or by a piped supply from an unpolluted source.

(3) The constituent materials and other components of these PPE classes must be so chosen or designed and incorporated as to ensure appropriate user respiration and respiratory hygiene for the period of wear concerned under the foreseeable conditions of use.

(4) The leak-tightness of the face piece and the pressure drop on inspiration and, in the case of the filtering devices, purification capacity must be such as to keep contaminant penetration from a polluted atmosphere low enough not to be prejudicial to the health or hygiene of the user.

(5) The PPE must bear the manufacturer's identification mark and details of the specific characteristics of that type of equipment which, in conjunction with the instructions for use, will enable a trained and qualified user to employ the PPE correctly.

(6) The manufacturer's notes must also in the case of filtering devices, indicate the deadline for the storage of filters as new and kept in their original packaging.

107.17.2 Protection against cutaneous and ocular contact

(1) PPE intended to prevent the surface contact of all or part of the body with dangerous substances and infective agents must be capable of preventing the penetration or diffusion of such substances through the protective integument under the foreseeable conditions of use for which the PPE is placed on the market.

(2) The constituent materials and other components of these PPE classes must be so chosen, or designed and incorporated as to ensure, as far as possible, complete leak-tightness, which will allow where necessary prolonged daily use or, failing this, limited leak-tightness necessitating a restriction of the period of wear.

(3) Where, by virtue of their nature and the foreseeable conditions of their use, certain dangerous substances or infective agents possess high penetrative power which limits the duration of the protection provided by the PPE in question, the latter must be subjected to standard tests with a view to their classification on the basis of efficiency.

(4) PPE which is considered to be in conformity with the test specifications must bear a mark indicating, in particular, the names or, failing this, the codes of the substances used in the tests and the corresponding standard period of protection.

(5) The manufacturer's notes must also contain, in particular, an explanation of the codes (if necessary), a detailed description of the standard tests and all appropriate information for the determination of the maximum permissible period of wear under the different foreseeable conditions of use.

107.18 Safety devices for diving equipment

107.18.1 Breathing equipment The breathing equipment must make it possible to supply the

user with a breathable gaseous mixture, under foreseeable conditions of use and taking account in particular of the maximum depth of immersion.

107.18.2 Where the foreseeable conditions of use so require, the equipment must comprise:

(1) a suit which protects the user against the pressure resulting from the depth of immersion (see 110.5) and/or against cold
(2) an alarm designed to give the user prompt warning of an approaching failure in the supply of breathable gaseous mixture
(3) a life-saving suit enabling the user to return to the surface

Safety Certification Standards

Installation of Electrical Attachment in Industrial Machinery and Equipment

Chapter 1 General provisions

1. Purpose

The purpose of this technical code is to define issues commissioned by the Article 27 of Occupational Safety and Health Law(hereinafter referred to as "OSH Law"), and Chapter 1 of Section 5 in Ministerial Decree of Occupational Safety and Health Regulation(hereinafter referred to as "Ministerial Decree"), for the prevention of occupational accidents due to failure or mal-function of electrical equipment and/or devices of industrial machinery and equipment.

2. Scope

2.1 This code shall be applied to machinery and its related electrical equipment and/or devices as follows;

(1) This code is applicable to the electrical equipment or parts of the electrical equipment that operate with normal supply voltage not exceeding 1,000 V for alternating current and not exceeding 1,500V for direct current, and nominal frequencies nor exceeding 200Hz.

(2) Additional and special requirements can apply to electrical equipment of machines as follows;
Machines which are used in open air(i.e. outside building or other protective structure).
Machine which use, process, or produce potentially explosive or inflammable materials.
Machines which are used in potentially explosive and/or flammable atmosphere.
Have special risks when producing or using certain materials
Mining machines.
Sewing machines

2.2 Power circuits where electrical energy is directly used as a working tool are excluded from this part of code.

3. Definitions

The definition of the terminology used in this code are as follows;

(1) Actuator means the part of the actuating system to which an external actuating force is applied.

(2) Control device means device connected into the control circuit and used for controlling the operation of the machine (e.g. position sensors, manual control switches, relays, magnetically operated valves).

(3) Control gear means a general term covering switching devices and their combination with associated control, measuring protective and regulating equipment, also as assemblies of such devices and equipment with associated interconnections, accessories, enclosures and supporting structures , intended in principle for the control of electrical energy consuming equipment.

(4) Controlled stop means the slopping of machine motion by reducing the command signal to 0 once the stop signal has been recognized by the control but retaining power to the machine actuators during the stopping process.

(5) Electrical operating area means a room or location for electrical equipment to which access is intended to be restricted to skilled or instructed persons, by opening of a door or the removal of a barrier without the use of a key or tool, and which is clearly marked by appropriated warning signs.

(6) Enclosed electrical operating area means a room or location for electrical equipment to which access is intended to be restricted to skilled or instructed persons, by opening of a door or the removal of a barrier without the use of a key or tool, and which is clearly marked by appropriated warning signs.

(7) Exposed conductive part means a conductive part of electrical equipment, which can be touched and which is not normally live, but which may become live under fault conditions.

(8) Guard means the part of a machine specifically used to provide protection by means of a physical barrier. Depending on its construction, a guard may be called casing, cover, screen, door, enclosing guard, etc.

(9) Interlock for safeguarding means an arrangement that interconnects the guard(s) or device(s) with the control system and/or all or part of the electrical energy distributed to the machine.

(10) Obstacle means apart preventing unintentional direct contact, but not preventing direct contact by deliberate action.

(11) Protective conductor means a conductor required by some measures for protection against electric shock for electrically connecting any of exposed conductive parts or main earthing terminal.

(12) Supplier means an entity (e.g. manufacturer, contractor, installer, integrator) thar provides equipment or services associated with the machine.

(13) Machinery (machine) means an assembly of linked parts or components, at least one of which moves, with the appropriate machine actuators, control and power circuits, etc. , joined together for a specific application, in particular for the processing treatment, moving or packaging of a material.

(14) TN

(15) TT

(16) IT

3.2 Unless otherwise defined hereunder, the terms used in this code shall have the meanings as defined in the OSH Law, the Enforcement Regulation and Ministerial Decree and related notification of Ministry of Labor and IEC standards.

4. General requirements

4.1 General considerations

4.1.1 The risks associated with the hazards relevant to the electrical equipment shall be assessed as part of the overall requirements for risk assessment of the machine,

4.1.2 Hazards can include but are not limited to the following:

(1) failures or faults in the electrical equipment resulting in the possibility of electrical fire
(2) failures or faults in control circuits (or components and devices associated with these circuits) resulting in malfunctioning of the machine
(3) disturbances or disruptions in external power sources as well an failures or faults in the power circuits resulting in the malfunctioning of the machine
(4) electrical interference (e.g. electromagnetic, electrostatic, radio interference) either from outside the electrical equipment or internally generated
(5) stored energy (either electrical or mechanical)
(6) audible noise at levels that cause health problems to persons

4.1.3 Safety measures are combination of the measures incorporated at the design stage and those measures required to be implemented by the user.

4.1.4 Design and development shall be the first consideration in the reduction of risks. Where this is not possible, safeguarding shall be considered.

4.2 Selection of equipment

Electrical components and devices shall be suitable for their intended us e.g. industrial (heavy, light), commercial, leisure, domestic, and shall comply with the KS, safety requirement for electrical apparatus and IEC standards where such exist.

4.3 Electrical supply

4.3.1 The electrical equipment shall be designed to operate correctly under full load as well as no load with the conditions of the nominal supply as specified below unless otherwise specified by the user.

(1) as specified in 4.3.2 or 4.3.3
(2) as otherwise specified by the user
(3) as specified by the supplier in the case of a special source of supply as an on-board generator.

4.3.1 AC supplies

(1) Steady state voltage shall be maintained and shall be 0.9 ~1.1 times of nominal voltage.
(3) Frequency shall be as follows;
In case of continuous modulation, frequency shall be 099~1.01 times of nominal frequency In shor time modulation, frequency shall be 0.98~1.01 times of nominal frequency.
(4) Harmonic distortion not to exceed 10% of the total r.m.s voltage between the live conductors for the sum of the 2nd through 5th harmonic An additional 2% max. of the total r.m.s voltage between the live conductors for the sum of the 6th through 30th harmonic is permissible.
(5) Voltage unbalance shall meet that neither the voltage of the negative sequence component nor voltage of the zero sequence component in 3-phase supplies shall exceed 2% of the positive sequence component.
(6) Voltage interruption shall meet that supply interrupted or at zero voltage for not more than 3 ms at any random time in the supply cycle. There shall be more than 1 s between successive interruptions.
(7) Voltage dips shall meet that voltage dips shall not exceed 20% of the peak voltage of the supply for more than one cycle. There shall be more than 1s between successive dips.

4.3.3 DC supplies

(1) From batteries
Battery voltage shall be 0.85 ~ 1.15 times of nominal voltage and shall be 0.7~1.2 times of nominal voltage in the case of battery-operated vehicles. Voltage interruption shall not exceed 5 ms.
(2) From converting equipment
Voltage shall be 0.9~1.1 times of nominal voltage. Voltage interruption shall not exceed 20 ms. There shall be more than 1 s between successive interruptions. Ripple (peak-to peak) does not exceed 0,05 of nominal voltage.

4.3.4 On-board power supply

For special supply systems such as on-board generation, the limits given 4.3.2 and 4.3.3 may be exceeded provided that the equipment is designed to operate correctly with those conditions.

4.4 Physical environment and operating conditions

The electrical equipment shall be suitable for use in the physical environment and operating conditions as specified below. When the physical environment and/or operating conditions are outside those specified, an agreement may be needed between the supplier and the user .

4.4.1 Electromagnetic compatibility(EMC)

(1) The electrical interferences(EMI) generated by the equipment itself shall not exceed levels specified in the relevant equipment standards and the appropriate level of electromagnetic immunity(EMS) shall be maintained.
(Note)1. European standard EN50081(1992) give general emission limits.
(Note)2. European standard EN50082-2(1995) give general immunity limits.
(Note)3. Product standards(e.g. IEC60439-1)may give more specific EMC requirements.

(2) In case of use the following electrical components, generated interference signals shall be kept to a minimum level. Suppression at the source by using capacitors, indctors, diodes, Zener diodes, varistors or active devices, or a combination of these. Screening of the equipment in a bonded electrically conductive enclosure to provide segregation from other equipment suppression at the source by using.

(3) Undesirable effects of electrostatic discharge, radiated electromagnetic energy and mains borne interference shall be avoided by using following methods. Use of appropriate filters and time delays Choice of certain power levels Suitable wiring types and practices

(4) In addition to the above, the effects of interference on equipment can be reduced by following methods. Reference potential circuit or common connections: each common connection is treated as a single circuit an connected to one of insulated conductors of large cross-sectional area (e.g. a minimum of 6mm^2 type class 6 (see table A.5)); Frame connections: in each piece of equipment all frame connections are to be taken to a common point and large section braided conductors used between slides and enclosures; the connections to the frame shall be as short as possible; Transmission of signals: using electrostatic screens, electromagnetic shields, twisted conductors and orientation (i.e. crossing cable runs at as near to 90 degrees as is practicable) as necessary to ensure that low level signal wiring is not affected by interference from control or power cables, or running the connections parallel to the ground plane as necessary; and Separation of equipment: separating and/or shielding sensitive equipment (e.g. units working with pulses and/or at low signal levels); from power cables.
(Note) Refer20.6 on electromagnetic compatibility tests.

4.4.2 Ambient air temperature

(1) Enclosed electrical equipment shall be capable of operating correctly in an ambient air temperature.

(2) The minimum requirement for all electrical equipment shall be capable of operating correctly in an ambient air temperature between +5 °C and +40 °C. For very hot environments(e.g. hot climates, steel mills, paper mills) and for cold environments, extra requirements may be necessary.

4.4.3 Humidity

(1) The electrical equipment shall be capable of operating correctly when the relative humidity does not exceed 50% at a maximum temperature of +40 °C .
(2) Harmful effects of occasional condensation shall be avoided by proper design of the equipment or, where necessary, by proper additional measures (e.g. built-in heaters, air conditioners, drain holes).

4.4.4 Altitude

Electrical equipment shall be capable of operating correctly at altitudes up to 1000 m above mean sea level.

4.4.5 Contaminants

Electrical equipment shall be adequately protected against the ingress of solid bodies and liquids (see 12.3). When the electrical equipment where contaminants(e.g. dust, corrosive gases, salt)are present in the physical environment in which the electrical is to be installed, an agreement may be needed between the supplier and the user.

4.4.6 Exposure to ionizing and non-ionizing radiation

When equipment is subject to radiation (e.g. microwave, ultraviolet, lasers, X-rays), additional measures shall be taken to avoid malfunctioning and accelerated deterioration of the insulation.

4.4.7 Vibration, shocks and bump

Undesirable effects of vibration, shock and bump (including those generated by the machine and its associated equipment and those created by the physical environment) shall be avoided by the selection of suitable equipment, by mounting it away from the machine, or by the us of anti vibration mountings.

4.5 Transportation and storage

Electrical equipment shall be designed to withstand, or suitable precautions shall be taken to protect against, the effects of transportation and storage temperature within a range of -25 °C

to +55°C and for short periods not exceeding 24h at up to +70°C. Suitable means shall be provided to prevent damage from humidity, vibration, and shock.

4.6 Provisions for handling

Heavy and bulky electrical equipment which has to be removed from the machine for transport, or which is independent of the machine, shall be provided with suitable means for handling by cranes or similar equipment. (See also 14.4.6).

4.7 Installation and operation

Electrical equipment shall be installed operated in accordance with the supplier's instructions and ergonomic principles should be taken into account

Chapter 2 Disconnecting and switching off of incoming supply

5. Incoming supply conductor terminations and devices for disconnecting and switching off

5.1 Incoming supply conductor terminations

(1) It is recommended that where practicable, the electrical equipment of a machine be connected to a single power supply. Where it is necessary to use another supply for certain parts of the equipment(e.g. electronic circuits, electromagnetic clutches), that supply should be derived, as far as possible, from devices(e.g. transformers, converters) forming part of the electrical equipment of the machine. For large complex machinery comprising a number of widely-spaced machines working together in a co-ordinated manner, there may be a need for more than one incoming supply depending upon the site supply arrangements.

(2) Unless a plug is provided with the machine for the connection to the supply (see 5.3.2), it is recommended that the supply conductors be directly connected o the supply terminals of the supply disconnecting device. When this is not practicable, separate terminals shall be provided.

(3) When a neutral conductor is used, it shall be clearly indicated in the technical documentation of the machine, such as in the installation diagram and the circuit diagram, and a separate insulate terminal, labelled N, shall be provided for the neutral conductor.

(4) There shall be no connection between neutral conductor and the protective bonding circuit inside the electrical equipment nor shall a combined PEN terminal be used inside the enclosure. A connection may be made between the neutral terminal and the PE terminal at the point of the connection of the power supply to the machine for TN-C system.

5.2 2 External protective connection of the external protective conductor

(1) For each incoming supply, a terminal shall be provided the vicinity of the associated phase conductor terminals (see 8.2.1) for connection of the machine to the external protective earthing system or to the external protective conductor, depending upon the supply distribution system, and in accordance with the relevant installation standards.
(2) The terminal shall be of such a size as to enable the connection of an external copper conductor with a cross-sectional area in accordance with table 1. Where an external conductor other than copper is used, the terminal size shall be selected accordingly (see also 8.2.2).

Table 1: Minimum cross-sectional area of the external protective copper conductor

Cross-sectional area of phase conductors supplying the equipment S (mm^2)	Minimum cross-sectional area of the external protective conductor(mm^2)
S 16	S
16 < S 35	16
S > 35	S/2

(3) The terminal for the external protective conductor shall be designated by marking with the letters PE.
(4) The use of the PE designation shall be restricted to the terminal for the connection of the protective bonding circuit of the machine to the external protective conductor of the incoming supply system.
(5) The other terminals used for the connection of machine components to the protective bonding circuit shall be identified by one of the following ways.
By graphic symbol :
By letter : PE
By use of bicolor combination GREEN-AND-YELLOW.

5.3 Supply disconnection(isolating) device

5.3.1 General

(1) Supply disconnecting (isolating)device shall be provided as following ways. A hand-operated supply disconnecting device shall be provided for each incoming supply to machine. This device shall be provided for source of supply to a feeder system using collector wires, collector bars, slip-ring assemblies, flexible cable systems(reeled, festooned), to a machine or a number of machines. This device shall be provided for each on0board power supply.

(2) The supply disconnecting device shall disconnect(isolate) the electrical equipment of the machine from the supply when required(e.g. for work on the machine, including the electrical rquipment).
(3) When two or more supply disconnecting devices are provided, protective interlocks shall be used where a hazardous condition or damage to the machine or the work in progress could occur.

5.3.2 Supply disconnecting type

(1) The supply disconnecting device shall be one of the following types:
a switch-disconnector
a disconnector which has an auxiliary contact which in all cases causes switching devices to break the load circuit before the opening of the main contacts of the disconnector;
a circuit-breaker
a plug/socket combination for a machine with a rated current not exceeding 16 A and a total power rating not exceeding 3 kW.
a plug and socket-outlet or an appliance coupler for a flexible cable supply(e.g. reeled, festooned) to a mobile machine under the following conditions:
(a) it shall not be possible to connect or disconnect a plug and socket-outlet or an appliance coupler, without breaking capacity, during load conditions
(b) the plug and socket-outlet of the appliance coupler shall be so connected that the part connected to the incoming supply is that which is protected to at least IP2X or IPXXB.
(2) Where a plug/socket combination is used , following requirement shall be fulfilled. It shall have a breaking capacity of at least the rated current of the machine at rated voltage. The rating should be at least locked rotor current. The electrical equipment shall have a device for switching the machine on and off.

5.3.3. Requirements

When the supply disconnecting device is one of the first three types specified in 5.3.2, it shall fulfil all of the following requirements.

(1) Isolate the electrical equipment from the supply and have one OFF and one ON position only, clearly marked with "O(Open)" and "I(Input)". Circuits breakers that, in addition, have a reset position between "O" and "I" are also deemed to satisfy this requirement.
(2) Have a visible gap or a position indicator which cannot indicate OFF until all contacts are actually open and there is an adequate isolating distance between all the contacts.
(3) Have an external operating black or grey handle. Where power operated switchgear need not be operable from outside the enclosure where are other means to open it, exception may be existed.

(4) Be provided with a means permitting it to be locked in the OFF position (e.g. by padlocks). When so locked, remote as well as local closing shall be prevented.
(5) Disconnect all live conductors of its power supply circuit. However, for TN supply systems, the neutral conductor may or may not be disconnected .
(6) Have a breaking capacity sufficient to interrupt the current of the largest motor when stalled together with the sum of the normal running currents of all other motors and/or loads.

5.3.4 Operating handle

The handle of the supply disconnecting device shall be easily accessible and located between 0.6m and 1.7m above the ground level.

5.3.5 Excepted circuits

(1) The following circuits need not be disconnected by the supply disconnecting device. Lighting circuits for lighting needed during maintenance or repair Plug/socket circuits for the exclusive connection of repair or maintenance tools and equipment (e.g. hand drills, test equipment). Under voltage protection circuits which are only used for automatic tripping in case of supply failure. Circuits supplying equipment which should normally remain energized for satisfactory operation (e.g. temperature controlled measuring devices, product (work in progress) heaters, program storage devices). Control circuits for interlocking in accordance with 14.1.3.
(2) It is recommended, however, that such circuits be provided with their own disconnecting device. Where such a circuit is not disconnected by the supply disconnecting device, the following measures shall be provided. A permanent warning label shall be appropriately placed in proximity to the supply disconnecting device. A corresponding statement shall be inserted in the maintenance manual. A permanent warning label shall be placed in proximity to each excepted circuit or the expected circuits shall be separated from other circuits. In case of control circuits for interlocking, identified by color according to 15.2.4.

5.4 Devices for switching off for prevention of unexpected start-up

(1) Where during maintenance a start-up of the machine can create a hazard, devices for switching off for the prevention of unexpected start-up shall be provided as follows; A supply disconnecting device (see 5.3.2) may fulfil this function. Such devices shall be appropriate and convenient for the intended use, shall be suitably placed, and readily identifiable. Means shall be provided to prevent inadvertent, and/or mistaken closure of the disconnecting device.
(2) In the following cases, means other than supply disconnecting devices in accordance with 5.3.2 are used (e.g. contactor switched by off by a control circuit). No significant

dismantling of the machine. Adjustments requiring a relatively short time. No work being carried out on the electrical equipment except when:

(a) there is no hazard arising from electric shock and burn;
(b) the switching off means cannot be negated by the work;
(c) the work is of a minor nature (e.g. replacement of plug-in devices without disturbing existing wiring).

5.5 Devices for disconnecting electrical equipment(Switches)

(1) Devices shall be provided for disconnecting(isolating)electrical equipment to enable work to be carried out without a risk from electric shock or burn.
(2) The supply disconnecting devices in accordance with 5.3 may fulfill the function of devices for disconnecting electrical equipment. However, where it is necessary to work on individual parts of the electrical equipment of a machine, or on one of a number of machine fed by a common collector bar or collector wire system, a disconnecting device shall be provided for each part, or for each machine, requiring separate isolation.
(3) Devices described in 5.3 may fulfill that function
(4) Disconnecters, withdrawable fuse links or withdrawable links may also may be used for that purpose, but only when located in an enclosed electrical operating area.
(5) Such disconnecting devices shall be as follows; appropriate and convenient for the intended use suitably located readily identifiable as to which part or circuits of the equipment is served provided with adequate means to prevent unauthorized, inadvertent, and mistaken closure of the disconnecting devices.

5.6 Protection against unauthorized, inadvertent and mistaken connection

The devices described in 5.5 that are capable of being equipped with means to lock them in the off position or disconnected state, in order to achieve protection against unauthorized, inadvertent, and mistaken connection, shall be equipped with such mean. Other means of protection against connection may be used where a non-lockable disconnecting device is located in an enclosed electrical operating area.

However, when a plug/socket combination used according to 5.3.2, is so positioned that it can be under the immediate supervision of the person carrying out the work, means for locking in the off position need not be provided.

6. Protection against electric shock

6.11 General
The electrical equipment shall provide protection of persons against electric shock from:

(7) direct contact; and

(8) indirect contact.

This shall be achieved by the application of the protective measures according to both 6.2 and 6.3. However, the use of PELV according to 6.4 takes care of both protection against electric shock from direct contact and from indirect contact.

6.2 Protection against direct contact

For each circuit or part of the electrical equipment, the measures of either 6.2.1 or 6.2.2 and, where applicable, 6.2.3 shall be applied.

6.2.1 Protection by enclosures

Live parts shall be located inside enclosures which comply with the relevant requirements of clauses 4, 13, and 16. Where the top surfaces of the enclosure and readily accessible, the minimum degree of protection against direct contact shall be IP4X or IPXXD (see EN 60529). Opening an enclosure (i.e. opening doors, lids, covers, and the like) shall only be possible under one of the following conditions:

a) The use of a key or tool is necessary for access by skilled or instructed persons to carry out operations for which it may not be means may be operated as needed while the door is open.

Examples of such operations are:

(9) replacement of fuse elements (i.e. those not requiring the use of a tool) ;
(10) replacement of plug-in devices and subassemblies;
(11) resetting of protective devices;
(12) adjustment of device settings (e.g. preset timers) ; and
(13) fault finding and diagnostic testing.

Live parts on the inside of doors shall be protected against direct contact to at least IP1X or IPXXA. Live parts which are likely to be touched when resetting or adjusting devices intended for such operations while the equipment is still connected shall be protected against direct contact to at least IP2X or IPXXB.

For rooms used as enclosures for electrical equipment which are accessible only to skilled persons, special requirements apply (see IEC 364-4-41, IEC 364-4-47, and EN 60439-1 as appropriate).

An obstacle intended to prevent unintentional contact with live parts (or accidentally touching them) does not prevent intentional contact.

b) The disconnection of live parts inside the enclosure before the enclosure may be opened.

This may be accomplished by interlocking the door with a disconnector(e.g. the supply disconnecting device) so that the door can only be opened when the disconnector is pen and so that the disconnector can only be closed when the door is closed. However, a special device or tool as prescribed by the supplier may permit skilled persons to defeat the inter lock provided that:

(14) It is possible at all times while the interlock is defeated to open the disconnector; and
(15) On closing the door, the interlock is automatically restored.

Where more than one door con provide access to live parts, care should be taken to implement the intent of this subclause.

All parts which are still live often switching off the disconnecting device(S) shall be protected against direct contact to at least IP2X or IPXXB(see EN 60529). Such parts shall be marked with a warning sign according to 18.2.

Excepted from this rule are the supply terminals of the supply disconnecting device when the latter is mounted alone in a separate enclosure.

c) Opening without the use of a key or a tool and without disconnection of live parts shall be possible only when all live parts are protected against direct contact to at least IP2X or IPXXB (see EN 60529). Where barriers provide this protection, either they shall require a tool for their removal or all live parts protected by them shall be automatically disconnected when the barrier is removed.

6.2.2 Protection by insulation of live parts

Live parts shall be completely covered with insulation which can only be removed by destruction. Such insulation shall be capable of withstanding the mechanical, chemical, electrical, and thermal stresses to which it can be subjected under normal service conditions.

Paints, varnishes, lacquers, and similar products alone are generally considered to be inadequate for protection against electric shock under normal service conditions.

6.2.3 Protection against residual voltages

Any exposed conductive part having a residual voltage greater than 60 V after the supply has been disconnected shall be discharged to 60 V or less within 5 s after disconnection of the supply, provided that this rate of discharge does not interfere with the proper functioning of the equipment. Exempted from this requirement are components having a stored charge of 60

C or less. Where such a provision would interfere with the proper functioning of the equipment, a warning notice drawing attention to the hazard and stating the delay required before the enclosure may be opened shall be durably displayed at an easily visible location on or immediately adjacent to the enclosure containing the capacitances.

In the case of plugs or similar devices, the withdrawal of which results in the exposure of conductors (e.g. pins), the discharge time shall not exceed 1 s, otherwise such conductors shall be protected against direct contact to at least IP2X or IPXXB.

6.3 Protection against indirect contact

Protection against indirect contact (see 3.27) is intended to prevent hazardous conditions in the event of an insulation failure between live parts and exposed conductive parts.

For each circuit or part of the electrical equipment, at least one of the measures according to 6.3.1, 6.3.2 and 6.3.3 shall be applied.

NOTE: For classes of equipment and protective provisions see IEC 536.

6.3.1 Protection by automatic disconnection of supply

Automatic disconnection of the supply after occurrence of an insulation failure is intended to prevent a touch voltage persisting for the time that a hazardous condition can arise.

This protective measure comprises both:

(16) the connection of exposed conductive parts to the protective bonding circuit (see clause 8) ; and
(17) the use of protective devices for the automatic disconnection of the supply in case of an insulation failure (see clause 7).

This protective measure necessitates coordination between the type of supply system and the characteristics of the protective devices for automatic disconnection in accordance with 413.1 of IEC 364-4-41.

6.3.2 Protection by use of class Ⅱ equipment or by equivalent insulation

This measure of protection shall be provided by one or more of the following measures:

(18) use of class Ⅱ electrical devices or apparatus (double insulation, reinforced insulation or by equivalent insulation in accordance with IEC 536);
(19) use of switchgear and control gear assemblies having total insulation in accordance

with EN 60439-1; and

(20) application of supplementary or reinforced insulation in accordance with 413.2 of IEC 364-4-41

6.3.3 Protection by electrical separation

Electrical separation of an individual circuit is intended to prevent shock current through contact with exposed conductive parts which can be energized by a failure in the basic insulation of the live parts of that circuit.

For this type of protection, the requirements of 413.5 of IEC 364-4-41 shall apply.

6.4 Protection by the use of PELV (Protective Extra Low Voltage)

This measure is intended to protect persons against electric shock from direct contact and indirect contact (see IEC 364-4-41).

PELV circuits shall satisfy all of the following conditions:

a) limitation of maximum nominal voltage to 25 V 1.c. or 60 V d.c.;
b) limitation of maximum current (in case of failure) to 1 A a.c. or 0.2 A d.c.;
c) limitation to 80mm2 of any area not protected against direct contact;
d) usage only indoors with dry conditions;
e) the source of supply and live parts of such circuits shall be separated or isolated from circuits with higher voltages according to 6.3.3 and 15.1.3;
f) one side of the circuit or one point of the source of the supply of that circuit shall be connected to the protective bonding circuit associated with the higher voltages;
g) exposed conductive parts associated with such circuits shall be either separated or isolated from higher voltage circuits in accordance with 6.3.3 or connected to the protective bonding circuit associated with the higher voltages;
h) plugs and socket-outlets shall comply with the following:
    1) plugs shall not be able to enter socket-outlets not in accordance with this subclause; and
    2) socket-outlets shall exclude plugs of circuits not in accordance with this subclause;
i) where such circuits are used as control circuits, they shall also fulfil the relevant requirements of clause 9.

7. Protection of equipment

7.1 General

This clause details the measures to be taken to protect equipment against the effects of:

(21) overcurrent arising from a short circuit;
(22) overload currents;
(23) abnormal temperatures;
(24) loss of or reduction in the supply voltage; and
(25) overspeed of machines/machine elements.

7.2 overcurrent protection

Overcurrent protection shall be provided as described below where the current in a machine circuit can exceed either the rating of any component or the current-carrying capacity of the conductors whichever is the lesser value. The settings to be used are detailed in 7.2.9.

7.2.1 Supply conductors

Unless otherwise specified by the user, the supplier of the electrical equipment shall not be responsible for providing the over current protective device for the supply conductors to the electrical equipment.

The supplier of the electrical equipment shall state on the installation diagram the data necessary for selecting this overcurrent protective device (see 7.2.9 and 19.5). (See annex B).

7.2.2 Power circuits

All conductors except earthed neutral conductors shall be protected against overcurrent by protective devices suitably chosen in accordance with 7.2.9. Devices for detection and interruption of overcurrent shall be inserted in all live conductors.

Where the cross-sectional area of an earthed neutral conductor (when used) is at least equal to that of the associated phase conductors, no overcurrent detection nor interruption is necessary in the neutral conductor.

For neutral conductors with a smaller cross-sectional area than the associated phase conductors, the measures detailed in item b) of 473.3.2.1 of IEC 364-4-473 shall apply.

In IT-Systems, it is recommended that the neutral conductor should not be used. However, where such a neutral conductor is used, it is generally necessary to provide overcurrent protection for this conductor (see also 473.3.2.2 of IEC 364-4-473).

7.2.3 Control circuits

Conductors of control circuits directly connected to the supply voltage and circuits feeding control circuit transformers shall be protected against overcurrent in accordance with 7.2.2.

7.2.4 Socket outlets and their associated conductors

Overcurrent Protection shall be required for the circuits feeding general Purpose socket outlets intended primarily for supplying power to maintenance equipment.

Overcurrent protective devices shall be provided in the unearthed live conductors of each circuit feeding such socket outlets.

7.2.5 Local lighting circuits

All unearthed conductors of circuits supplying local lighting shall be protected against the effects of short circuits by overcurrent devices separate from those protecting other circuits.

7.2.6 Transformers

Transformers shall be protected against overcurrent in accordance with IEC 76-5 and EN 60742 as appropriate. Such protection shall(see also 7.2.9):

(26) avoid nuisance tripping due to transformer magnetizing inrush currents; and
(27) avoid a winding temperature rise in excess of the permitted value for the insulation class of transformer when it is subjected to the effects of a short circuit at its secondary terminals.

The type and setting of the overcurrent protective device should be in accordance with the recommendations of the transformer supplier.

7.2.7 Location of overcurrent protective devices

Overcurrent protective devices shall be located at the point where the conductors to be protected are connected to their supply. Where this is not possible, no overcurrent protection is required for those circuit conductors with couuent carrying capacity less than that of the supply conductors provided that the possibility of a short circuit is reduced by all of the following measures:

(28) the current-carrying capacity of the conductors is at least equal to that required for the load;
(29) each connecting conductor to the overcurrent protective device is no longer than 3 m: and
(30) the conductors are protected by an enclosure or duct.

7.2.8 Overcurrent protective devices

The breaking capacity shall be at least equal to the prospective short circuit current at the

point of installation.

A lower breaking capacity is permitted where another protective device (e.g. the supply conductors overcurrent protective device – see 7.2.1) having the necessary breaking capacity is installed on the supply side. In that case, the characteristics of the devices shall be coordinated so that the energy let-through of the two devices in series does not exceed that which can be withstood without damage by the overcurrent protective device on the load side and the conductors protected by this device. The instantaneous release of the device on the supply side shall be adjusted to a current value of at least 20% below the current which can safely be interrupted by the device on the lode side.

Overcurrent protective devices for power circuits include fuses and circuit-breakers. For control circuits, electronic devices designs to reduce or limit the current in protected circuits may also be used. Where fuses are sued, a type readily available in the country of use shall be selected.

7.2.9 Rating and setting of overcurrent protective devices

The rated current of fuses or the setting current of other overcurrent protective devices shall be selected as low as possible but adequate for the anticipated overcurrents, e.g. during starting of motors or energizing transformers. When selecting these protective devices, devices in case of overcurrent, e.g. against welding of the control switching device contacts.

The rated current or setting of an overcurrent protective device is determined by the current-carrying capacity of the conductors to be protected by that device in accordance with 1.4. This shall take into account the needs of coordination with other electrical devices in the protected circuit. The recommendations of the supplier of these devices shall be followed.

7.3 Overload protection of motors

Overload protection of motors shall be provided for each motor rated at more than 0,5 kW which is normally in continuous operation. Such overload protection is recommended for all other motors, especially for coolant pump motors. Overload protection of motors can be achieved by the use of devices such as overload protective devices, temperature sensing devices, current limiting devices.

NOTE: Overload protective devices detect time/current relationships in a circuit which are in excess of the rated full load of the circuit and initiate appropriate control responses.

Detection of overload(s) (except in the case of current limitation or built-in thermal protection, e.g. thermistors embedded in motor windings) shall be provided in each live conductor but not in the neutral conductor. However, the number of overload detection

devices may be reduced at the request of the user(see annex B). For motors having single phase or d.c. power supplies, detection in only one unearthed live conductor is permitted.

Where overload protection is achieved by switching off, the switching device shall switch off all live conductors except for the neutral conductor.

In the case of motors with special duty ratings which are called upon to start or to brake frequently (e.g. motors used for rapid traverse, locking, rapid reversal, sensitive drilling), it may be difficult to provide overload protection with a time constant comparable with that of the wining to be protected. The use of appropriate protective devices designed to accommodate special duty motors is recommended. For such motors with ratings not exceeding 2 kW, overload protection is not required.

The use of motors with built-in thermal protection (see IEC 34-11) is recommended in situations where the cooling can be impaired (e.g. dusty environments). Depending upon the kind of motor, built-in thermal protection may not ensure sufficient protection under stalled rotor conditions and therefore it may be necessary to provide additional protection under these conditions.

Automatic restarting of any motor after the operation of overload after the operation of overload protection shall be prevented where the can cause a hazardous condition or damage to the machine or to the work in progress.

7.4 Abnormal temperature protection

Resistance heating or other circuits, which are capable of attaining or causing abnormal temperatures and therefore can cause a hazardous condition, shall be provided with suitable detection to initiate an appropriate control response. An example could be a resistance heating circuit which either is short-time rated or loses its cooling medium.

7.5 Protection against supply interruption or voltage reduction and subsequent restoration

Where a voltage drop or a supply interruption can cause malfunctioning of the electrical equipment, an undervoltage device shall be provided which shall ensure appropriate protection (e.g. switching off the machine supply) at a predetermine voltage level.

Where the operation of the machine can allow for an interruption or a reduction of the voltage for a short time period, a delayed undervoltage device may be provided. The operation of the undervoltage device shall not impair the operation of any stopping control of the machine.

Automatic restarting of the machine shall be prevented after the operation of the undervoltage device where such restart can cause a hazardous condition, or damage to the machine or to the

work in progress.

In cases where only a part of the machine or of the group of machines working together in a coordinated manner is affected by the voltage reduction or supply interruption, a means shall be provided on the affected part to allow monitoring by the rest of the system to ensure the requirements of this subclause are met.

7.6 Motor overspeed protection

Overspeed protection shall be provided in cases where over speeding can cause a hazardous condition taking into account measures according to 9.4.2. Overspeed protection shall initiate appropriate control responses and shall prevent automatic restarting.

8. Equipotential bonding circuit

8.2.1 General

The protective bonding circuit consists of:

(31) the PE terminal (see 5.2);
(32) the conductive structural parts of the electrical equipment and the machine; and
(33) the protective conductors in the equipment of the machine.

All parts of the protective bonding circuit shall be so designed that they are capable of withstanding the highest thermal and mechanical stresses that can be caused by earth-fault currents that could flow in that part of the protective bonding circuit.

Any structural part of the electrical equipment or of the machine may be used as part of the protective bonding circuit provided that the cross-sectional area of the part is at least electrically equivalent to the cross-sectional area of the copper conductor required.

8.2.2 Protective conductors

Protective conductors shall be identified in accordance with 15.2.2

Copper conductors should be used. Where a conductor material other than copper is used, its electrical resistance per unit length shall not exceed that of the allowable copper conductor and such conductors shall not be less that 16mm2 in cross-sectional area.

The cross-sectional area of protective conductors shall be determined in accordance with the requirements of 543.1 of IEC 364-5-54 and 7.4.3.1.7 of EN 60439-1 as appropriate.

This requirement is met in most cases where the relationship between the cross-sectional area

of the phase conductors associated with that part of the equipment and the associated protective conductors in accordance with table 1.

8.2.3 Continuity of the protective bonding circuit

All exposed conductive pats of the electrical equipment and the machine(s) shall be connected to the protective bonding circuit.

The resistance of any part of the protective bonding circuit shall not allow a hazardous touch voltage to be present on exposed conductive parts in the event of an insulation failure (see 543.2 and 543.3 of IEC 364-5-54).

Connection and bonding points shall be designed so that their current-carrying capacity is not impaired by mechanical, chemical, or electrochemical influences. Where enclosures and conductors of aluminium or aluminium alloys are used, particular consideration shall be given to the problems of electrolytic corrosion.

Metal conduits of flexible or rigid construction and metallic cable sheaths shall not be used as protective conductors. Nevertheless such metal conduits and the metal sheathing of all connecting cables (e.g. steel conduit, armoring, lead sheath) shall be connected to the protective bonding circuit.

Where the electrical equipment is mounted on lids, doors, or cover plates, continuity of the protective bonding circuit shall be ensured. This shall not depend upon fastenings, hinges, or support rails and the protective conductor(s) shall be associated with the conductors energizing the equipment.

Where no electrical equipment is attached to lids, doors, or cover plates or when only PELV circuits are present, the metal hinges and the like are considered sufficient to ensure continuity.

Where a part is removed for any reason (e.g. routine maintenance), the protective bonding circuit for the remaining parts shall not be interrupted.

8.2.4 Exclusion of switching devices from the protective bonding circuit
The protective bonding circuit shall not incorporate switching or overcurrent devices (e.g. switch, fuse) nor means for current detection for such devices. The only means for interruption permitted in the protective conductors shall be links which can be opened only by instructed or skilled persons for certain test or measurement purposes, ferablygy using a tool.

It is permissible to include such devices that do not interrupt the protective bonding circuit, that have electrical characteristics which under all circumstances ensure prevention of a

hazardous voltage rise in any part of the circuit, and that do not impair the performance of the circuit.

8.2.5 Parts which need not be connected to the protective bonding circuit

It is not necessary to connect exposed conductive parts to the protective bonding circuit where these parts are mounted so that they do not constitute a hazard because:

(34) they cannot be touched on large surfaces or grasped with the hand and the are small in size (less than approximately 50 mm ×50 mm); or
(35) they are located so that contact with live parts or an insulation failure is unlikely.

This applies to small parts such as screws, rivets, and nameplates and to parts inside an enclosure, irrespective of their size (e.g. electromagnets of contractors or relays, mechanical parts of devices).

8.2.6 Interruption of the protective bonding circuit by connectors

Where the continuity of the protective bonding circuit can be interrupted by means of connectors or plug/socket combinations, the protective bonding circuit shall be interrupted only after the live conductors have been interrupted, and the continuity of the protective conductors have been interrupted, and the continuity of the protective bonding circuit shall be re-established before any live conductor is reconnected. This also applies to removable or withdrawable plug-in units.

Metallic housings of connectors and plug/socket combinations shall be connected to the protective bonding circuit except where used for PELV.

8.2.7 Protective conductor connecting points

All protective conductors shall be terminated in accordance with 15.1.1. It is not permissible to connect protective conductors to fittings used to attach or connect appliances or parts.

Each protective conductor connecting point shall be identified as such using the symbol 417-IEC-5019. Alternatively, terminals for the connection of the protective conductor may be identified by the bi-colour combination GREEN-AND-YELLOW. The letters PE are reserved for the terminal for the connection of the external protective conductor (see 5.2).

8.3 Bonding to the protective bonding circuit for operational purposes

The objective of operational bonding is to minimize:

(36) the consequences of an insulation failure on the safety of persons or on the machine or

on the work in progress; and

(37) the consequences of interference on the operation of sensitive electrical equipment (see 8.6).

8.4 Insulation failures

One method for protection against unintended operation as a result of insulation failures is achieved by connecting one side of the control fed by transformers to the protective bonding circuit with the control devices connected in accordance with 9.1.4. This connection shall be made at the source of the control circuit supply. The connection may also form part of the protective bonding circuit (see 7.2.3). In the case of electronic circuits see also 9.4.3.1.

Attention is drawn to the fact that by omitting the connection of the exposed conductive parts of the devices to the protective bonding circuit as permitted by 6.3.2 and 6.3.3, the safety measures of this safety measures of this subclause may not be effective.

8.5 Bonding to a common reference potential

Bonding to a common reference potential other than that provided by the protective bonding circuit or to the terminal for connection to an external (noiseless) earth conductor shall be permitted provided the requirements of clauses 6 and 7 are met.

Single point bonding connected directly to a point as close as point as close as possible to the PE terminal (see figure 3(2)) or to its own terminal for connection to n external (noiseless) earth conductor shall be employed, where appropriate, to minimize common mode interferences (see figure 3(3)). This latter terminal shall be identified by the symbol 417-IEC-5018.

8.6 Electrical inter ference

The effects of interference can be reduced by employing a low resistance conductor in a low impedance network which is used s a reference level for higher frequency signals within the electrical equipment(e.g. the chassis or ground plane). Such termination points shall be identified by the symbol 417-IEC-5020. The design of the bonding connections shall be such as to reduce the impedance to the ground plane as much as possible.

9. Control circuits and control functions

9.1 Control circuits

9.1.1 Control circuit supply

Transformers shall be used for supplying the control circuits. Such transformers shall have separate windings. Where several transformers are used, it is recommended that the windings of these transformers be connected in such a manner that the secondary voltages are in phase.

Where d.c. control circuits are connected to the protective bonding circuit (see 8.2.1), they shall be supplied from a separate winding of the a.c. control circuit transformer or from another control circuit transformer.

Transformers are not mandatory for:

(38) machines having a rated power less than 3 kW with a single motor starter and a maximum of two external control devices(e.g. interlock device, emergency stop push-button) ; and
(39) domestic and similar machines where the electrical equipment is contained within the machine enclosure.

9.1.2 Control circuit voltages

The value of the control voltage shall be consistent with the correct operation of the control circuit. The nominal voltage shall not exceed 250 V when supplied from a transformer.

9.1.3 Protection

Control circuits shall be provided with overcurrent protection in accordance with 7.2.3 and 7.2.9. Overload protection may be provided.

9.1.4 Connection of control devices

In control circuits with one side connected (or intended to be connected) to the protective bonding circuit (see 7.2.3), one terminal (preferably always having the same marking) of the operating coil of each electromagnetically operated device or one terminal of any other electrical device shall be connected directly to that side of the control circuit. All switching functions (e.g. contacts) of control devices which operate the coil or the device shall be inserted between the other terminal of the coil or device and the other side of the control circuit terminal of the coil or device and the other side of the control circuit (i.e. that which is not connected to the protective bonding circuit).

The following exceptions are permitted:

(40) contacts of protective devices (e.g. overload relays) may be connected between that side connected to the protective bonding circuit and the coils, provided that the conductors between that side connected to the protective bonding circuit and the coils,

provided that the conductors between such and the coils of the control devices on which the relay contacts operate are in the same control enclosure and the connection is so short and of a type that an earth fault is unlikely; and

(41) where the requirements of 9.4.3.1 are met.

9.2 Control functions

9.2.1 Start functions

Start functions shall operate by energizing the relevant circuit, (See 9.2.5.2)

9.2.2 Stop functions

There are three categories of stop functions as follows:

(42) Category 0 : stopping by immediate removal of power to the machine actuators (i.e. an uncontrolled stop, see 3.59);

(43) Category 1 : a controlled stop (see 3.12) with power to the machine actuators available to achieve the stop and then removal of power when the stop is achieved;

(44) Category 2 : a controlled stop with power left available to the machine actuators.

Each machine shall be equipped with a category 0 stop. Category 1 and/or category 2 stops shall be provided where demanded by the safety and/or functional requirements of the machine. Category 0 and category 1 stops category 0 stop shall take priority. Stop functions shall operate by de-energizing the relevant circuit and shall override related start functions (see 9.2.5.3 and 9.2.5.4.)

9.2.3 Operating modes

Each machine can have one or more operating modes determined by the type of machine and its application.

When hazardous conditions can arise from mode selection, such selection shall be prevented by suitable means (e.g. key operated switch, access code). Mode selection by itself shall mot initiate machine operation. A separate action by the operator shall be required.

Safeguarding means shall remain EFFECTIVE FOR ALL OPERATING MODES (See 9.2.4 for suspension of safeguards under special conditions).

9.2.4 Suspension of safeguards

Where it is necessary to suspend one or more safeguards, a mode selection device or means

capable of being secured (e.g. locked) in the desired mode shall be provided to prevent automatic operation (see also 4.1.4 of EN 292-2). In addition, one or more of the following measures should be provided:

(45) initiation of motion by a hold-to-run or equivalent control device;
(46) a portable control station (e.g. pendant) with an emergency stop device. Where a portable station is used, motion may be initiated only from that station;
(47) limiting motion speed or power; and
(48) limiting the range of motion.

9.2.5 Operation

9.2.5.1 General

The necessary interlocks (see 9.3) shall be provided for safe operation.

9.2.5.2 Start

The start of an operation shall be possible only where all the safeguards are in place and functional, except for conditions as described in 9.2.4.

Suitable interlocks shall be provided to secure correct sequential starting.

(n machines requiring the use of more than one control station to initiate a start:

(49) each control station shall have a separate manually actuated start control device;
(50) all required conditions for machine operation shall be met;
(51) all start control devices shall be in the released (off) position before a start may be permitted; and
(52) all start control devices shall be actuated concurrently.

9.2.5.3 Stop

The choice of category of stop shall be determined from the risk assessment of the machine (see 4.1). In addition, appropriate measures to ensure a reliable stop shall be required (see 9.4). (Principles for the design of safety-related parts of control systems are under consideration by CEN/TC 114).

Where required, facilities to connect protective devices and interlocks shall be provided. Where applicable, the stop function shall signal the logic of the control system that such a condition exists. The reset of the stop function shall not initiate any hazardous conditions.

9.2.5.4 Emergency stop

Functional aspects of emergency stop equipment are given in EN 481.

In addition to the requirements for stop (see 9.2.5.3), the emergency stop has the following reuirements:

(53) it shall override all other functions and operations in all modes;
(54) power to the machine actuators which can cause hazardous conditions shall be removed as quickly as possible without creating other hazards (e.g. by the provision of mechanical means of stopping requiring no external power, by reverse current braking for a category 1 stop) ; and
(55) reset shall not initiate a restart.

Where required, facilities to connect additional emergency stop devices shall be provided (see 10.7 for the requirements of emergency stop devices.)

The emergency stop shall function as either a category 0 or a category 1 stop (see 9.2.2). The choice of the category of the emergency stop shall be determined by the risk assessment of the machine.

Where a category 0 stop is used for the emergency stop function, it shall have only hardwired electro mechanical components. In addition, its operation shall not depend on electronic logic (hardware or software) or on the transmission of commands over a communications network or link.

Where a category 1 stop is used for the emergency stop function, final removal of power to the machine actuators shall be ensured and shall be by means of electro mechanical components.

9.2.5.5 Monitoring of command actions

Any movement or action of a machine or part of a machine which can result in a hazardous condition shall be carried out with monitoring of the position or result of that movement or action.

9.2.5.6 Hold-to-run controls

Hold-to-run controls shall require continuous actuation of the control devices(s) to achieve operation.

9.2.5.7 Two-hand control

Three types of two-hand control are available, the selection of which is determined by the risk assessment. These shall have the following features (performance requirements of two-hand control devices are under consideration by CEN/TC 114):

Type 1: This type requires:

(56) the provision of two control actuating devices requiring concurrent actuations by both hands;
(57) continuous actuation during the hazardous condition; and
(58) machine operation shall cease on release of either control actuating device when hazardous conditions are still present.

Type 2: A type 1 control requiring the release of both control actuating devices before machine operation may be reinitiated.

Type 3: A type 2 control requiring synchronous actuation of the control actuating devices as follows;

(59) it shall be necessary to actuate the control actuating devices within a certain time limit of less than or equal to 0,5 seconds of each other (see annex B) ; and
(60) where the time limit is exceeded, both control actuating devices shall be released before operation may be initiated.

9.2.6 Combined start and stop controls

Push-button and similar device controls which alternately initiate and stop motion shall only be used for secondary functions where no hazardous condition can arise when they are operated.

9.3 Protective interlocks

9.3.1 Restoration of interlocked safeguards

The restoring of an interlocked safeguard shall not initiate machine motion or operation where this can give rise to a hazardous condition.

9.3.2 Overtravel limits

Where an overtravel can cause a hazardous condition, a limiting device shall be fitted to interrupt the power circuit of the relevant machine actuator(s).

9.3.3 Operation of axillary functions

The correct operation of auxiliary functions shall be checked by appropriate devices (e.g. pressure sensors).

Where the non-operation of any motor or device for an auxiliary function (e.g. lubrication, coolant, swarf removal) can cause a hazardous condition, or cause damage to the machine or to the work in progress, appropriate interlocking shall be provided.

9.3.4 Interlocks between different operations and for contrary motions

All contractors, relays, and other control devices which control elements of the machine that can cause a hazardous condition when actuated at the same time (e.g. those which initiate contrary motion) shall be interlocked against incorrect operation.

Reversing contractors (i.e. those controlling the direction of a motor) shall be interlocked in such a way that in normal service no short circuit can occur when switching.

Where, for safety or for continuous operation, certain functions on the machine are required to be interrelated, proper coordination shall be ensured by suitable interlocks. For a group of machines working together in a coordinated manner and having ore than one controller, provision shall be made to coordinate the operations of the controllers as necessary.

9.3.5 Reverse current braking

Where haverse current braking is used on a motor, effective measures shall be taken to avoid the motor starting in the opposite direction at the end of braking where this reversal can cause a hazardous condition or curse damage to the machine or to the work in progress. For this purpose, the use of a device operating exclusively as a function of time shall not be allowed.

Control circuits shall be arranged so that rotation of a motor shaft, manually or otherwise, shall not give rise to a hazardous condition.

9.4 Control functions in case of failure

9.4.1 General requirements

Where failures or disturbances in the electrical equipment can cause a hazardous condition or cause damage to the machine or to the work in progress, appropriate measures shall be taken to minimize the probability of such hazards occurring. The required measures and the extent to which they are implemented, either individually or in combination, depend on the level of risk associated with ath respective application (see 4.1).

Measures to reduce these risks include but are not limited to:

(61) protective devices on the machine (e.g. interlock guards, trip devices);
(62) protective interlocking of the electrical circuit;
(63) use of proven circuit techniques and components (see 9.4.2.1);
(64) provision of partial or complete redundancy (see 9.4.2.2) or diversity (see 9.4.2.3); and
(65) provision for functional tests (see 9.4.2.4).

In general, only single failures are to be regarded. In the event of higher levels of risk, it may be necessary to ensure that a single failure cannot give rise to a hazardous condition.

9.4.2 Measures to minimize risk in case of failure

9.4.2.1 Use of proven circuit techniques and components

These measures include but are not limited to:

(66) bonding of control circuits for operational purposes (see 9.4.3.);
(67) one terminal of the control device (i.e. the operating coil) connected to the bonded conductor and all switching functions (e.g. contacts) connected to the non-earthed side of the control supply (see 9.1.4);
(68) stopping by de-energizing (see 9.2.2);
(69) switching of all live conductors to the device being controlled (see 9.4.3.1);
(70) use of switching devices having positive opening operation (see EN 60947-5-1); and
(71) circuit design to reduce the possibility of failures causing undesirable operations.

9.4.2.2 Provisions for redundancy

By providing partial or complete redundancy it is possible to minimize the probability that one single failure in the electrical circuit can give rise to a hazard. Redundancy can be effective in normal operation(i.e. on-line redundancy) or designed as special circuits which take over the protective function(i.e. off-line redundancy) only where the operating function fails.

Where off-line redundancy which in not active during normal operation is used, suitable measures shall be taken to ensure that these control circuits are available when required.

9.4.2.3 Use of diversity

The use of control circuits having different principles of operation or differing types of devices may reduce the probability of faults and failures giving rise to hazards. Examples include:

(72) the combination of normally open and normally closed contacts operated by

interlocking guards;

(73) the use of different types of control circuit components in the circuit;

(74) the combination of electro mechanical and electronic circuits in redundant configurations; and

(75) the combination of electrical and non-electrical systems (e.g. mechanical, hydraulic, pneumatic) may perform the redundant function and provide the diversity.

9.4.2.4. Functional tests

Functional tests may be carried out automatically, by the control system, or manually by inspection or tests at start-up and at predetermined intervals, or a combination as appropriate (see also 19.2 and 20.7).

9.4.3 Protection against maloperations due to earth faults and voltage interruptions

9.4.3.1 Earth faults

Earth faults on control circuits shall not cause unintentional starting, hazardous movements, or prevent stopping of the machine.

In order to fulfil this requirement, bonding to the protective bonding circuit shall be provided in accordance with 8.2 and the devices shall be connected as described in 9.1.4. Control circuits fed from a transformer and not connected to the protective bonding circuit shall be provided with an insulation monitoring device (e.g. residual current device) which either indicates an earth fault or interrupts the circuit automatically after an earth fault.

In the case of electronic circuits, the connection of one side of the control circuit to the protective bonding circuit in accordance with 9.1.4. can prevent unintentional operation. When this does not help, or if due to other reasons electronic circuits cannot be connected to the protective bonding circuit, other measures shall be taken to achieve the same level of safety.

Where the control circuit is directly connected between the phase conductors of the supply or between a phase conductor and a neutral conductor which either is not earthed or is earthed through a high impedance, multi-pole control switches which interrupt all live conductors shall be used for start or stop of those machine functions which can cause a hazardous condition, or damage to the machine or to the work in progress in the event of unintentional starting or failure to stop.

9.4.3.2 Voltage interruptions

The requirements detailed in 7.5 shall apply.

Where a memory is used, proper functioning in the event of power failure shall be ensured (e.g. by using a non-volatile memory) where shch loss of memory can give rise to a hazardous condition.

10. Operator interface and machine mounted control devices

10.1 General

This clause contains requirements for devices mounted outside or partially outside control enclosures.

As far as is practicable, these devices shall be selected, mounted, and identified or coded in accordance with IEC 73 and IEC 447. (A European Standard on indicating, marking and actuating principles is under consideration by CENELEC/TC 44X).

10.1.1 Location and mounting

As far as is practicable, machine mounted control devices shall be:

(76) readily accessible for service and maintenance; and
(77) mounted in such a manner as to minimize the possibility of damage from handling equipment or from other mobile equipment.

The actuators of hand-operated control devices shall be selected and installed so that:

(78) they are not less than 0,6 m above the servicing level and are within easy reach from the normal working position of the operator;
(79) the operator is not placed in a hazardous situation when operating them; and
(80) the possibility of inadvertent operation is minimized.

10.1.2 Protection

Where mounted as intended, operator interface and machine mounted control devices shall withstand the stresses of the expected use and shall have a minimum degree of protection of IP 54, but preferably IP 55 (see EN 60529). The degree of protection together with other appropriate measures shall afford protection against:

(81) the effects of aggressive liquids, vapours or gases found in the physical environment or used on the machine; and
(82) the ingress of contaminants (e.g. swarf, dust, particulate matter).

10.1.3 Position sensors

Position sensors (e.g. position switches, proximity switches) shall be so arranged that they will not be damaged in the event of over travel.

Mechanically actuated position sensors used in circuits intended to provide a protective measure shall be designed for positive opening operation(see EN 60947-5-1).

10.2 Push-buttons

10.2.1 Colours

Push-button actuators shall be colour-coded in accordance with table 2.

The colours for START/ON actuators should be WHITE, GREY or BLACK with a preference for WHITE. GREEN is also permitted. RED shall not be used.

The colour RED shall be used for emergency stop actuators. The colours for STOP/OFF actuators should be BLACK, GREY or WHITE with a preference for BLACK. RED is also permitted. GREEN shall not be used.

WHITE, GREY, and BLACK are the preferred colours for push-button actuators which alternately act as START/ON and STOP/OFF push=buttons. The colour RED, YELLOW, or GREEN shall not be used (see also 9.2.6).

WHITE, GREY, and BLACK are the preferred colours for push-button actuators which cause operation while they are actuated and cease the operation when they are released (e.g. hold-to-run). The colour RED, YELLOW, or GREEN shall not be used.

The colour GREEN is reserved for functions indicating a safe or normal condition.

The colour YELLOW is reserved for functions indicating caution or abnormal condition.

The colour BLUE is reserved for functions of mandatory significance.

Reset push-buttons shall be BLUE, WHITE, GREY, or BLACK. Where they also act as a STOP OFF button, the colour WHITE, GREY, or black is preferred with the main preference being for BLCK. GREEN shall not be used.

10.2.2 Markings

In addition to the functional identification as described in 18.3, it is recommended that push-buttons be marked with symbols, near or preferably directly on the actuators, for example:

START or ON STOP or OFF push-buttons which act alternately as START and STOP Or ON and OFF Buttons push-buttons that cause a movement while they are pressed and stop movement when they are released (i.e. hold-to-run)

417-IEC-5007 417-IEC-5008 417-EIC-5010 417-IEC-5011

Table 2: Colour-coding for push-button actuators and their meanings

Colour	Meaning	Explanation	Examples of application
RED	Emergency	Actuate in case of hazardous condition or emergency	Emergency stop Initiation of emergency function See also 10.2.1
YELLOW	Abnormal	Actuate in case of abnormal condition	Intervention to suppress abnormal condition Intervention to restart an interrupted automatic cycle
GREEN	Safe	Actuate in case of safe situation or to prepare normal conditions.	See 10.2.1
BLUE	Mandatory	Actuate in case of condition requiring mandatory action.	Reset function
WHITE	No specific	For general initiation of functions except emergency stop	START/ON(preferred) STOP/OFF
GREY	Meaning	(See also note)	START/ON STOP/OFF
BLACK	assigned		START/ON STOP/OFF(preferred)

NPTE: Where a supplemental means of coding (e.g texture, shape, position) is used for the identification of push-button actuators, then the same colour WHITE, GREY, or BLACK may be used for various functions (e.g. WHITE for START/ON and STOP/OFF actuators)

Table 3: Colours for indicator lights and their meanings with respect to the condition of the machine

Colour	Meaning	Explanation	Action by operator	Examples of application
RED	Emergency	Hazardous condition	Immediate action to deal with hazardous condition (e.g. by operating emergency stop)	Pressure/temperature out of safe limits Voltage drop Breakdown Overtravel of a stop position
YELLOW	Abnormal	Abnormal condition; Impending critical condition	Monitoring and/or intervention (e.g. by re-establishing the intended function)	Pressure/temperature exceeding normal limits Tripping of protective device
GREEN	Normal	Normal condition	Optional	Pressure/temperature within normal limits Authorization to proceed
BLUE	Mandatory	Indication of condition which requires action by the operator	Mandatory action	Instruction to enter preselected values
WHITE	Neutral	Other conditions; maybe used whenever doubt exists about the application of RED, YELLOW, GREEN, BLUE	Monitoring	General Information

10.3 Indicator lights and displays

10.3.1 Modes of use

Indicator lights and displays serve to give the following types of information:

(83) Indication : to attract the operator's attention or to indicate that a certain task should be performed. The colours RED, YELLOW, GREEN, and BLUE are normally used in this mode.

(84) Confirmation : to confirm a command, a state or condition, or to confirm the termination of a change or transition period. The colours BLUE and WHIT are normally used in this mode and GREEN may be used in some cases.

10.3.2 Coloures

Unless otherwise agreed between the supplier and the user, indicator(pilot)light lenses shall be colour-coded with respect to the condition(status)of the machine in accordance with table 3. In accordance with IEC 73 alternative meanings may be assigned according to one of the following criteria:

(85) the safety of persona and environment; or
(86) the state of the electrical equipment

10.3.3 Flashing lights

For further distinction or information and especially to give additional emphasis, flashing lights may be used for the following purposes:

(87) to attract attention;
(88) to request immediate action;
(89) to indicate a discrepancy between the command and actual states; and
(90) to indicate a change in process(flashing during transition).

It is recommended that higher frequency flashing lights be used for higher priority information.

10.4 Illuminated push-buttons

Illuminated push-button actuators shall be colour-coded in accordance with table 2 and 3. Where there is difficulty in assigning an appropriate colour, WHITE shall be used. The colour RED for the emergency stop actuator shall not depend on the illumination of its light.

10.5 Rotary control devices

Devices having a rotational member, such as potentiometers and selector switches, shall be mounted in such a way as to prevent rotation of the stationary member. Friction alone not be sufficient.

10.6 Start devices

Actuators used to initiate a start function or the movement of machine elements (e.g. slides, spindles, carriers)shall be constructed ad mounted so as to minimize in advertent operation. Mushroom-type actuators may be used for two-hand control.

10.7 Emergency stop devices

10.7.1 General

Emergency stop devices shall be located at each operator station and at other operating stations where emergency stop may be required.

10.7.2 Types

The types of emergency stop devices include:

(91) a push-button operated switch:
(92) a pull-cord operated switch: and
(93) a pedal-operated switch without a mechanical guard.

The devices shall be of the self-latching type and shall be positioned so as to be readily accessible.

10.7.3 Characteristics

It shall not be possible to restore the circuit until the actuator of the emergency stop device has been manually reset. Where several emergency stop devices are provided, the circuit shall not be restored until all actuators previously operated have been reset.

The contacts of manually operated emergency stop devices shall ensure positive opening operation.

10.7.4 Actuators

Actuators of emergency stop devices shall be coloured RED. Where background exists behind the device actuator. It shall be coloured YELLOW. The actuator of a push-button operated switch shall be of the palm or mushroom head type.

10.7.5 Use of means of disconnection

On certain machines where the provision of emergency stop devices of the type described in

10.7.2 are considered to be unnecessary, the supply disconnecting device may serve the function of an emergency stop device. In such cases and for those disconnecting devices described in 5.3.2 a), b) and c), the colour requirement shall be in accordance with 10.7.4

10.8 Displays

Displays (e.g. visual display unit, alarm annuciators)shall be selected and installed in such a manner as to be visible from the normal position of the operator. In the case where displays are intended to be warning devices, it is recommended that they are of the flashing luminary type and should be accompanied by ab audible warning device.

11. Control interfaces

11.1 General

This clause deals with the requirements for signals between the numerical control or programmable controller and various external devices, in particular digital input and output devices and velocity and servo drives. The requirements for wiring between the numerical control or programmable controller and the external devices are specified in clauses 14 and 15.

11.2 Digital input/output interfaces

For each digital (I/O) signal, the numerical control programmable controller shall have at least one suitable termination (e.g. pin connector, screw terminal) together with a sufficient number of termination for common and shield connections. It is recommended that an individual common connection be provided with each signal termination.

11.2.1 Inputs

One side of each input device shall be connected to one side of the input voltage supply circuit, the other side of each input device to the appropriate input terminal. The other side of the input voltage supply circuit should be connected to the protective bonding circuit at the common terminal of the supply. The input circuits should be isolated from the internal circuits of the numerical control or programmable controller by the use of transformers, optical couplers or other high impedance devices, together with insulated conductors.

Input devices shall be connected through a normally open contact except where considerations of failure require the normally closed contact (e.g. stop function).

11.2.2 outputs

One side of each output load shall be connected to the common side of the output supply which in turn should be connected to the protective bonding circuit.

Each output module or circuit should be connected to only one output device.

When connecting inductive loads to the outputs of the numerical control or programmable controller, it shall be ensured that the switching of the inductive loads is in accordance with the recommendations of the numerical control or programmable controller supplier, In addition, interference suppression shall be provided across the windings of motors that are started and stopped while the numerical control or programmable controller is energized.

11.3 Drive interfaces with analogue inputs

11.3.1 Separation between control and electric drives

The drive supplier shall ensure that a differential input is used between the numerical control and the drive control circuits except for any common connections to the protective bonding circuit. This includes any means for measuring motor armature current. The drive shall not be sensitive to common mode signals between its input terminals and the frame.

11.3.2 Hydraulic servo-valves

The numerical control supplier shall provide, where required, output current to the hydraulic servo-valve proportional to the commanded axis velocity or shall advise the machine supplier of appropriate voltage to current conversion devices.

11.3.3 Electric servo and velocity drives

It is recommended that, where the velocity command or following error signal from the numerical control to the electric servo or velocity drive is analogue, ±10V corresponds to maximum motor speed or maximum torque.

11.4 Peripherals

Peripheral devices (e.g. display terminals, printers) shall be connected and utilized in accordance with the supplier's recommendations.

11.5 Communications

Communications systems and networks shall be incorporated in accordance with appropriate CENELEC and CEN, or IEC and ISO standards. Where the machine and its associated

equipment is to be connected to a communications network (i.e. the transmission of commands and data between the machine and a remote controller), the network interface should preferably be in accordance with appropriate ECNELEC and CEN, or IEC and ISO standards, and with the supplier's recommendations. In such cases, the equipment shall be provided with a key-operated switch or equivalent means which will 'lock-out' any commands from the remote controller which can result in a hazardous condition. The circuit which the switch operates shall allow control of machine functions only by persons in the immediate vicinity of the machine.

12. Electronic equipment

12.1 General

This clause applies to all types of electronic device including programmable electronic equipment, subassemblies, printed circuit boards, devices, and components.

12.2 Basic requirements

12.2.1 Inputs and outputs

Status indication of digital inputs and outputs should be provided.

12.2.2 Electronic control equipment

Electronic control equipment (e.g. numerical and programmable controllers) shall receive power from the electrical supply of the machine. Supplies shall be derived from a dedicated or a common transformer. For further requirements, see 9.1.1.

12.2.3 Equipotential bonding

All input/output racks (remote or local), processor racks, and power supplies shall be electrically bonded together in accordance with the supplier's specifications and the protective bonding circuit (see 8.2.3).

Where it is necessary for operational purposes for some equipment to be isolated from the protective bonding circuit, such equipment may be excluded from this requirement in compliance with clause 8.

12.3 Programmable equipment

12.3.1 Programmable controllers

Programmable controllers shall comply with relevant IEC standards (see IEC 131).

12.3.2 Memory retention and protection

Means shall be provided to prevent memory alteration by unauthorized persons and the requirements detailed in 9.4.3.2 shall apply.

12.3.3 Programming equipment

For safety-related reasons, the supplier may retain the right not to allow the user to alter the program.

The use of the programming equipment shall not interfere with the data communications interfacing.

12.3.4 Software verification

Equipment using reprogrammable logic shall have means for verifying that the software is in accordance with the relevant program documentation.

12.3.5 Use in safety-related functions

Programmable electronic equipment shall not be used for category 0 emergency stop functions (see 9.2.5.4).

For category 1 emergency stop functions and all other safety-related stop functions, the use of hardwired electro mechanical components is preferred (i.e. the function should not depend on the operation of programmable electronic equipment, see 9.2.5.4). Where programmable electronic equipment is used for such functions, then appropriate measures in accordance with 9.4 shall be employed.

These requirements shall not preclude the use of programmable electronic equipment for monitoring, testing or backing-up such function, but this equipment shall not prevent the correct operation of those functions.

NOTE: It is believed at present that it is difficult to determine, with any degree of certainty in situations when a significant hazard can occur due to maloperation of the control system, that reliance on correct operation of a single channel of programmable electronic is inadvisable to rely solel on the correct operation of such a single channel device.

13. Control gear: location, mounting and enclosures

13.1 General requirements

All control gear shall be located and mounted to facilitate accessibility and maintenance and

shall be protected against the external influences or conditions under which the machine is intended to operate.

13.2 Location and mounting

13.2.1 Accessibility and maintenance

All items of control gear shall be placed and oriented so that they can be identified without moving them or the wiring. For items which require checking for correct operation or which are liable to need replacement, these actions should be possible without dismantling other equipment or parts of the machine (except opening doors and removing covers). Terminals not associated with control gear shall also comply with these requirements.

All control gear shall be mounted so as to facilitate operation and maintenance from the front. Where a special tool is necessary to remove a device, such a tool shall be supplied. (The appropriate dimensions for the entrance and workspace are under consideration by CEN/TC 122). Where access is required for regular maintenance or adjustment, the relevant devices shall be located between 0,4 m and 2,0 m above the servicing level. It is recommended that terminals be at least 0,2 m above the servicing level and so placed that conductors and cables can be easily connected to them

No devices except those for operating, indicating, measuring and cooling shall be mounted on doors, and normally removable access covers, of enclosure

There control devices are connected through plug-in arrangements, their association shall be made clear by type (shape), marking or designation (or a combination of these) (see 15.4.5).

Plug-in devices which are handled during normal operation shall be provided with on-interchangeable features where the lack of such a facility can result in malfunctioning. Plug/socket combinations which are handled during normal operation shall ne locked and mounted as to provided unobstructed access.

Test points, where provided, shall be:

(94) mounted so as to provide unobstructed access;
(95) clearly marked to correspond with the documentation
(96) adequately insulated; and
(97) sufficiently spaced for connection of the test equipment or means

13.2.2 Segregation

Control gear shall be mounted so that it does not interfere with operation and maintenance of

the machine and its associated equipment.

Non-electrical parts and devices, not directly associated with the electrical equipment, shall not be located within enclosures containing control gear. Devices such as solenoid valves should be separated from other electrical equipment.

Control devices, mounted in the same location and connected to the supply voltage or to both supply and control voltages, shall be grouped separately from those connected only to the control voltages. Terminal blocks for power circuits shall be grouped separately from those for control circuits. However grouped power terminals may be mounted adjacent to control terminals provided that each group can be readily identified (e.g. by use of different sizes, by use of barriers, by colour).

When arranging the location old devices (including interconnections), the clearance and creepage distances specified for them shall be maintained, taking into account the external influences or conditions of the physical environment.

13.2.3 Heating effects

Heat generating components (e.g. heat sinks, power resistors)shall be located so that the temperature of each component in the vicinity remains within the permitted limit.

13.3 Degrees of protection

The protection of control gear against ingress of solid foreign objects and liquids shall be adequate, taking into account the external influences under which the machine is intended to operate (i.e. the location and the physical environmental conditions), and shall be sufficient against dust, coolants, swarf and mechanical damage.

Enclosures of control gear shall provide a degree of protection of at least IP54.

Exceptions to this requirement of minimum protection are:

(98) ventilated enclosures containing only motor starting resistors, dynamic braking resistors, or similar equipment: IP22

(99) motors : IP23

(100) ventilated enclosures containing other equipment : IP33

The above are minimum degrees of protection. A higher degree of protection may be necessary depending upon the installation conditions e.g. control gear in a location which is cleaned by water jets should be protected to at least IP66.

Control gear exposed to fine dust shall be protected to at least IP65.

13.4 Enclosures, doors and openings

Fasteners used to secure doors and covers should be of the captive type. Windows provided for viewing internally mounted indicating devices shall be of a material suitable to withstand mechanical stress and chemical attack e.g. toughend glass, poly-carbonate sheet (3mm thick).

It is recommended that enclosures doors should have vrtical hinges, preferably of the lift-off type, with an angle of opening of at least 56°, and should be not wider than 0.9m.

Enclosures which readily allow a person fully to enter shall be provided with means to allow escape, e.g. for servicing maintenance, shall have a clear width of at least 0.7m and a clear height of at least 2m. In cases where:

(101) equipment is likely to be live during access; and
(102) conducting parts are exposed

the clear width shall be at least 1.0m. In cases where such parts are present on both sides of the access way the clear width shall be at least 1.5m.

The joints or gaskets of doors, lids, cover and enclosures, shall withstand the chemical effects of aggressive liquids, vapours or gases, used on the machine. The measures used to maintain the degree of protection of an enclosure on doors, lids, and covers which require opening or removal for operation or maintenance:

(103) shall be securely attached to either door/cover or the enclosure; and
(104) shall not deteriorate by virtue of removal or replacement of the door or cover and so impair the degree of protection.

All openings in the enclosure, including those towards the floor or foundation or to other parts of the machine, shall be closed by the supplier(s) in a manner ensuring the degree of protection specified for the equipment. Openings for cable entries shall be easily re-opened on site. A suitable opening may be provided in the base of enclosures within the machine so that moisture due to condensation may drain away.

There shall be no opening between enclosures containting electrical equipment and compartments containing coolant, lubricating or hydraulic fluids, or those into which oil, other liquids, or dust can penetrate. This requirement does not apply to electrical devices specifically designed to operate in oil (e.g. electromagnetic clutches) nor to electrical equipment in which coolants are used.

Where there are holes in an enclosure for mounting purposes, care shall be taken so that after mounting, the holes do not impair the required protection.

14. Conductors and cables

14.1 General requirements

Conductors and cables shall be selected so as to be suitable for the operating conditions (e.g. voltage, current, protection against electric shock, grouping of cables) and external influences (e.g. ambient temperature, presence of water or corrosive substances, mechanical stresses) which can exist.

Wherever possible, insulated conductors and cables which have flame-retardant properties shall be used.

These requirements do not apply to the integral wiring of assemblies, subassemblies and devices, which are manufactured and tested in accordance with their relevant European Standards or IEC standards(e.g. EN 60439-1).

14.2 Conductors

In general, conductors shall be of copper. Conductors of any other material shall have a nominal cross-sectional area such that, carrying the same current, the maximum conductor temperature shall not exceed the values given in table 4. Where aluminium is used, the cross-sectional area shall be at least 16 mm^2

Although class 1 conductors are primarily intended for use between rigid, non-moving parts, they may also be used where minimal flexing occurs provided that the cross-sectional area is less than 0,5 mm^2. All conductors which are subject to frequent movement (i.e. one movement/hour of machine operation) shall have flexible stranding of classed 5 or 6 (see table C.5).

14.3 Insulation

The types of insulation include (but are not limited to):

(105) polyvinyl chloride (PVC);
(106) rubber, natural and synthetic;
(107) silicone rubber (SiR);
(108) mineral;
(109) cross-linked polyethylene (XLOPE); and
(110) ethylene propylene compound (EPR).

Where insulated conductors and cables can constitute a fire hazard due to the propagation of a fire or the emission of toxic or corrosive fumes (e.g. PVC), guidance from the cable supplier

should be sought. In particular it is important to maintain the integrity of circuits having a safety function (e.g. emergency stop) for as long as possible under these conditions.

The dielectric strength of the insulation shall be adequate for the required test voltage (see also 15.1.3). For cables operating at voltages higher than 50 V a.c. or 120 V d.c. the test voltage is a minimum of 2000 V a.c. for a duration of 5 min. For separate PELV circuits, the test voltage is 500 V a.c. for a duration of 5 min.

The mechanical strength and thickness of the insulation shall be such that the insulation cannot be damaged in operation or during laying, especially for cables pulled into ducts.

14.4 Current carrying capacity in normal service

The current carrying capacity of conductors and cables is determined by both:

(111) the maximum allowable conductor temperature under the highest possible steady state current under normal conditions; and
(112) the ultimate allowable short-time conductor temperature under short-circuit conditions.

A conductor cross-sectional area shall be such that for the highest steady state current or its equivalent the conductor temperature does not exceed the value given in table 4.

Table 4: Maximum allowable conductor temperatures under normal and short-circuit conditions

Types of insulation	Maximum conductor temperature under normal conditions (℃)	Ultimate short-time conductor temperature under short-circuit conditions (see Note) (℃)
Polyvinyl chloride (PVC)	70	160
Rubber	60	200
Cross-linked polyethylene (XLPE) Ethylene propylene compound (EPR)	90	250
Silicone rubber (SiR)	180	350

NOTE: Assuming adiabatic behaviour for a period of not more than 5 s.

For continuous duty the current-carrying capacity for external wiring is given in table 5. For the selection of conductors and cables for intermittent duty applications, see C. Where cables use aluminium instead of copper conductors, a derating factor of 0,78 shall be applied to the values in table 5.

14.5 Voltage drop

The voltage drop shall not exceed 5 % of the nominal voltage. In order to comply with this requirement, it may be necessary to use conductors having a larger cross-sectional area than that derived from table 5.

14.6 Minimum cross-sectional area

To ensure adequate mechanical strength, the cross-sectional area of the conductors should not be less than those shown in table 6. However, conductors with smaller cross-sectional areas than those shown in table 6 may be used in equipment where necessary, provided adequate mechanical strength is achieved by other means and proper functioning is not impaired. The wiring of circuits with a maximum current of 2 A, located within an enclosure, need not comply with the requirements of table 6.

To ensure adequate

15.1 Connections and routing

15.1.1 General requirements

All connections, especially those of the protective bonding circuit,
Shall be secured against accidental loosening.

The means of connection shall be suitable for the cross-sectional areas and nature of the conductors being terminated. In the case of aluminum or aluminum alloy conductors, particular consideration shall be given to the problems of electrolytic corrosion (see 14.2)

The connection of two or more conductors to one terminalis permitted only in those cases where the terminal is designed for that purpose. However, only one protective bonding circuit conductor shall be connected to one terminal connection point.

Soldered connections shall only be permitted where terminals are provided which are suitable for soldering.

Terminals on terminal blocks shall be plainly identified to correspond with marking on the diagrams.

The installation of flexible conduits and cables shell be such that liquids shell drain away from the fittings.

Means of retaining conductor strand shall be provided when terminating conductors at devices or terminals which are not equipped with this facility. Solder shall not be used for this purpose.

Shielded conductors shall be so terminated as to prevent fraying of strands and to permit easy connection.

Identifications tags shall be legible, permanent, and appropriate for the physical environment.

Terminal blocks shall be so mounted and wired, that the internal and external wiring does not cross over the terminals(see EN 60947-7-1)

15.1.2 Conductor and cable runs

Conductors and cables shall be run from terminal to terminal without splices or intervening joints.

Where it is necessary to connect and disconnect cables and cable assemblies, sufficient extra length shall be provided for this purpose.

The terminations of multicore cables shall be adequately supported where undue strain can be exerted on the terminations of the conductors.

Wherever possible, the protective conductor shall be placed close to the associated live conductors in order to decrease the impedance of the loop.

15.1.3 Conductors of different circuit

Conductors of different circuits may be laid side by side, may occupy the same duct(e.g. conduct, cable trunking system), or may be in the same multi-conductor cable provided that the arrangement does not impair the proper functioning of the respective circuits. Where these circuits operate at different voltages, the conductors shall be either separated by suitable barriers or insulated for the highest voltage to which any conductor within the same duct can be subjected.

Circuits which are not switched off by the supply disconnecting device shall be either physical separated from other wiring or distinguished by colour(or both) so that can be identified as being live when the disconnecting device is in the OFF or OPEN position(see 5.3.5).

15.2 Identification of conductors

15.2.1 General requirement

Conductors shall be identifiable at each termination in accordance with the technical documentation(see clause 19).

Where colour-coding is used for identification of conductors, the following colours may used:

BLACK
BROWN
RED
ORANGE
YELLOW
GREEN
BLUE(including LIGHT BLUE)
VIOLET
GRAY
WHITE
PINK
TURQUOISE

NOTE: This list of colours is derived from IEC 757

It is recommended that, where colour is used for identification, the colour be used throughout the length of the conductor either by the colour of the insulation or by colour markers. An acceptable alternative may consist of additional identification at selected locations.

For safety reasons, the colour GREEN or the colour YELLOW shall be not be used where there is a possibility of confusion with the bicolor combination GREEN-AND-YELLOW(see 15.2.2).

Colour identification using combinations of those colours listed above may be used provided there can be no confusion and that GREEN or YELLOW is not used, except in the bicolor combination GREEN-AND-YELLOW.

15.2.2 Identification of the protective conductor

The protective conductor shall be readily distinguishable by shape, location, marking or colour. When identification is by colour alone, the bicolor combination GREEN-AND-YELLOW shall be used throughout the length of the conductor. This colour identification is strictly reserved for the protective conductor

NOTE-Not used.

For insulated conductors, the bicolor combination GREEN-AND-YELLOW shall be such that on any 15mm length one of the colours covers at least 30% and not more than 70% of the surface of the conductor, the other colour covering the remainder of the surface.

Where the protective conductor can be easily identification by its shape, position or construction (e.g. braided conductor), or where the insulated conductor is not readily assessable position shall be clearly identification but the ends or accessible position shall be clearly identification by the graphical symbol 417-IEC-5019 or by the bicolor combination GREEN-AND-YELLOW).

15.2.3. Identification of the neutral conductor

There a circuit includes a neutral conductor identification by colour, the colour shall be LIGHT BLUE(see 3.1.2 of IEC 446). LIGHT BLUE shall not be used for identifying any other conductor where confusion is possible.
NOTE-Not used.

In the absence of a neutral conductor, a LIGHT BLUE conductor may be used for other purpose except for used as a protective conductor.

Where identification by colour is used, bare conductors used as neutral conductors shall be either coloured by a LIGHT BLUE stripe, 15mm to 100mm wide, in each compartment or unit or at each accessible position, or coloured LIGHT BLUE throughout their length.

15.2.4 Identification of other conductors

identification of other conductors shall be by colour (either solid or with one or more strips), number, alpha number, or a combination of colour and numbers or alpha number. When numbers are used, they shall be Arabic; letters shall be Roman (either upper or lower case).

Insulated single-core conductors should be colour-coded as follows :
- BLACK : a.c. and d.c. power circuit;
- RED: a.c. control circuit;
- BLUE : d.c. control circuit; and
- ORANGE : interlock control circuit supplied from an external power source (see 15.1.3)

NOTE – Not used.

Exceptions to the above are permitted:
- for internal wiring on individual devices purchased completely wired;
- where insulation is used that is not available in the colours required; or
- where multi conductor cable is used, but not the bicolor combination GREEN and YELLOW.

15.3 Wiring inside enclosures

Panel conductors shall be supported where necessary to keep them in place. Non- metallic channels or ducts shall be permitted only when made with a flame-retardant insulating material (see IEC 332-1)

It is recommended that electrical equipment mounted inside enclosures be designed and constructed in such a way as to permit modification of the wiring from the front of the enclosure (see also 13.2.1). Where this not possible and control devices are connected from the rear of the enclosure, access doors or swing out panels shall be provided.

Connections to devices mounted on doors or to other movable parts shall be made using flexible conductors in accordance with 14.2 to allow for the fixed part and the movable part independently of the electrical connections (see also 8.2.3 and 13.2.1).

Conductors and cables which do not run in ducts shall be adequately supported.

Terminal blocks or attachment plug/socket combinations shall be used for control wiring which extends beyond the enclosure.

Power cables ad cables of measuring, circuits may be directly connected to the terminals of the devices for which the connections were intended.

15.4 Wiring outside enclosures

15.4.1 General requirements

The means of introduction of Cables or ducts with their individuai glands, bushings, etc., into an enclosure shall ensure that the degree of protection is not reduced (see 13.3).

15.4.2 External ducts

Conductors and their connections. External to the electrical equipment enclosure(s) shall be enclosed in suitable ducts (i.e. conduit or cable trunking systems) a described in 15.5, except for suitably protected cables which may be installed without enclosing ducts and with or without the use of open cable trays or cable support means.

Fittings sued with ducts or multi conductor cable shall be suitable for the physical environment.

Flexible conduit or flexible multi conductor cable shall be used where it is necessary to employ flexible connections to pendant push-button stations. The weight of pendant stations

shall be supported by means other than the flexible conduit or the flexible multi conductor cable, except where the conduit or cable is specifically designed for that prupose.

Flexible conduit or flexible multi conductor cable be used for connections involving small or infrequent movements. They shall also be permitted to complete the connection to normally stationary motors, to position switches, and to other externally mounted devices.

15.4.3 Connection to moving elements of the machine

Connections to frequently moving parts shall be made with conductors suitable for flexing service in accordance with 14.2 Flexible cable and flexible conduit shall be so installed as to avoid excessive flexing and straining particularly at the fittings.

Cables subject to movement shall be supported in such a way that there is no mechanical strain on the connection points or any sharp blending. The loop shall have sufficient length to provide for a bending radius of the cable of at least ten times its outside diameters.

Where cable subject to movement are close to moving parts, precautions shall be taken so that a space of least 25 mm shall be maintained between the moving parts and the cables. Where this distance is not practicable, fixed barriers shall be provided between the cable and the moving parts.

The cable sheath shall be resistant to the normal wear which can be expected from movement, and to the effects of atmospheric contaminants (e.g. oil, water, coolants, dust).

Where flexible conduit is adjacent to moving parts, the construction and supporting means shall prevent damage to the flexile conduit or cable under all conditions of operation.

Flexible metallic conduit shall not be used for rapid or frequent movements, except when specifically designed for that purpose.

Rewired devices (e.g. position switches, proximity switches) provided which an identified cable may be provided without provisions for termination of the conduit.

Conductors connected to a.c. circuits and conductors connected to d.c circuits shall be permitted in the same duct regardless of voltage provided they are all insulated for the maximum voltage of any conductor in the duct.

15.4.4 Interconnection of devices on the machine

It is recommended that, where several machine-mounted switching devices (e.g. position sensors, push-buttons) are connected in series or in parallel , the conductors between those

devices be returned to terminals forming intermediate test points. The terminals shall be conveniently placed, adequately protected, and shown on the relevant diagrams.

15.4.5 Plug and socket connections

Where equipment is removable, connections though a polarized attachment plug/socket combination shall be permitted. The male plug shall be connected to the load side of the circuit. PELV circuits are excepted from this requirement.

The plug/socket combination shall be so designed that the protective bonding circuit connection is made before any live connections are made, and is not disconnected until all live conductors in the plug are disconnected (see also 6.2.3), except theose according to 6.4 for those used only to facilitate assembling/disassembling (multiple connectors).

Plug/socket combinations which are rated at more than 16 A or which remain connected during normal service shall be of the retaining type to prevent disconnection. Plug/socket combinations rated at 63 A or above shall be of a type interlocked with a combined switch.

The Plug/socket combinations shall be of a type which will prevent unintentional contact with live parts at any time, including during insertion or removal of the connectors.

Plug/socket combinations shall be of adequate size and shall have sufficient contact pressure and wiping action to ensure proper electrical continuity. Clearances between contacts shall be adequate for the voltages used and shall be maintained during insertion and removal of the connectors.

Where more then one plug/socket combination is used in the same electrical equipment , they shall be clearly identified. It is recommended that mechanical coding be used to prevent incorrect insertion .

Sockets of a type according to EN 60309-1 or used for domestic applications shall not be used for control circuits.

15.4.6 Dismantling for shipment

Terminals in an accessible enclosure or attachment plug/socket combinations shall be provided at the sectional points where it is necessary that wiring be disconnected for shipment. Such terminals or connectors shall be inherently protected from the physical environment or suitably enclosed.

15.4.7 Additional conductors

Consideration should be given to providing additional conductors for maintenance or repair.

When spare conductors are provided, they shall be Connected to spare terminals or isolated in such a manner as to prevent contact with live parts.

15.5 Ducts, connection and junction boxes

15.5.1 General requirements

All sharp edges, flash, burrs, rough surfaces, or threads, with which the insulation of the conductors may come in contact, shall be removes from ducts and fitting. Where necessary, additional protection consisting of a flame-retardant, oil-resistant insulating material shall be provided to protect conductor insulation.

Duct shall provide a minimum degree of protection of IP33.

Drain holes of 6mm diameter shall be permitted in cable trunking systems, junction boxes and pull boxes which are subject to accumulations of oil or moisture.

In order to prevent confusion of electrical conduits with piping for oil, air, or water, it is recommended that the electrical conduits be either physically separated or suitably identified.

Ducts and cable trays shall be rigidly supported and positioned at a sufficient distance from moving parts and in such a manner so as to minimize the possibility of damage or wear. In areas where human passage is required, the ducts and open cable trays shall be mounted to give at least 2m clearance for such passage.

Ducts and connection boxes are provided for mechanical protection only.

15.5.2 Percentage fill of ducts

Consideration on the fill percentage should be based on the straightness and length of the duct and flexibility of the conductors. It is recommended that the dimensions and arrangement of the duct be such as to facilitate the insertion of the conductors and cables.

15.5.3 Rigid metal conduit and fittings

Rigid metal conduit and fittings shall be of galvanized steel or a corrosion-resistant material suitable for the conditions. The use of dissimilar metals in contact, which can cause galvanic action, should be avoided.

Conduit shall be securely held in place and supported at each end.

Fitting shall be compatible with the conduit and appropriate for the application. Fittings shall

be threaded unless structural difficulties prevent assembly. Where threadless fittings are used, the conduit shall be securely fastened to the equipment.

Conduit bends shall be so made that the conduit is not be damaged and the internal diameter of the conduit is not effectively reduced.

15.5.4 Flexible metal conduit and fittings

Flexible metal conduit shall consist of flexible metal tubing or woven wire armour and shall be suitable for the expected physical environment.

Fittings shall be compatible with the conduit and appropriate for the application.

15.5.5 Flexible non-metallic conduit and fittings

Flexible non-metallic conduit shall be resistant to kinking and shall have physical characteristics similar to those of the sheath of multi conductor cables.

The conuit shall be suitable for the expected physical environment and for use at expected ambient temperatures.

Fittings shall be compatible with the conduit and appropriate for the application.

15.5.6 Cable trunking systems

Cable trunking systems external to enclosures shall be rigidly supported and clear of all moving or contaminating portions of the machine.

Covers shall be shaped to overlap the sides; gaskets shall be permitted. Covers shall be attached to cable trunking systems by hinges or chains, and held closed by means of captive screws or other suitable fasteners. On horizontal cable trunking systems, the cover shall not be on the bottom.

Where the cable trunking system is furnished in sections, the joints between sections shall fit tightly but need not be gasketed.

There shall be no openings other than those required for wiring or for drainage. Cable trunking systems shall not have opened unused knockouts.

15.5.7 Machine compartments and cable trunking systems

The use of compartments or cable trunking systems within the column or base of a machine to

enclose conductors shall be permitted provided the compartment or cable trunking system is isolated from coolant or oil reservoirs and is entirely enclosed. Conductors run in enclosed compartments and cable trunking systems shall be secured and so arranged that they will not be subject to physical damage.

15.5.8 Terminals, connection and junction boxes

Terminals shall be placed in easily accessible enclosures. Connection and through boxes (including any openings) mounted on the machine(s) shall provide a degree of protection of at least IP 44 (see EN 60529). The joints or gaskets of these boxes shall withstand the foreseen effects of the physical environment, including any contaminants.

Connection and junction boxes shall not have opened unused knockouts nor any other openings and shall be so constructed as to exclude materials such as dust, oil and coolant.

15.5.9 Motor connection boxes

Motor terminal boxes shall enclose only connections to the motor and motor-mounted devices (e.g. brakes, temperature sensors, plugging switches, tachometer generators).

16. Electric motors and associated equipment

16.1 general requirements

Motors should comply with the requirements of IEC 34-1.

Motors and associated equipment shall be protected against:

- overload in accordance with 7.3;
- overspeed in accordance with 7.6;
- field failure of d.c. motors by the use of current detection or overspeed protection; and
- overcurrent in accordance with 7.2 (see also IEC 146).

As many controllers do not switch off the supply to the motor when it is at rest, care shall be taken to ensure compliance with the requirements of 5.3, 5.4, 7.5, 7.6 and 9.4. Motor control equipment shall be located and mounted in accordance with clause 13.

16.2 Motor enclosures

It is recommended that motor enclosures be chosen from those included in EN 60034-5.

The degree of protection shall be at least IP 23 for all motors. More stringent requirements

may be needed depending on the application and the physical environment (see 4.4). In the case of a.c. d.c. motors used in light industrial equipment, additional protection shall be supplied as necessary. Motors incorporated as an integral part of the machine shall be so mounted that they are adequately protected mechanically.

16.3 Motor dimensions

As far as is practicable, the dimensions of the motors shall comply with those given in IEC 72-1 and IEC 72-2.

16.4 Motor mounting and compartments

Each motor and its associated couplings shall be so mounted so that they are adequately protected and are easily accessible for inspection, maintenance, adjustment and alignments, lubrication, and replacement. The motor mounting arrangement shall be such that all motor hold-down means can be removed and terminal boxes are accessible.

Motors shall be mounted so that proper cooling is ensured and the temperature rise remains within the limits of the insulation class (see IEC 34-1).

Where possible, motor compartments should be clean and dry, and where required, shall be ventilated directly to the exterior of the machine. The vents shall be such that ingress of swarf, dust or water spray is at an acceptable level.

There shall be no opening between the motor compartment and any other compartment which does not meet the motor compartment requirements. Where a conduit or pipe is run into the motor compartment from another compartment not meeting the motor compartment requirements, any clearance around the conduit or pipe shall be sealed.

Moving members associated with the motor(s) which present a hazard shall be guarded or enclosed so as to reduce the risk.

16.5 Motor nameplates

Where the motor is mounted so that its nameplate is not directly visible, a second nameplate shall be mounted near the motor where it is clearly visible.

A second nameplate shall also be provided where the service or environmental conditions require the motor to be rated differently.

Where the reversal of the direction of rotation can produce a hazardous condition, a direction arrow shall be mounted adjacent to the motor where it is clearly visible.

16.6 Criteria for selection

The characteristics of motors and associated equipment shall be selected in accordance with the anticipated service and physical environmental conditions (see 4.4). In this respect, the points which shall be carefully considered include:

- type of motor;
- type of duty cycle (see IEC 34-1);
- fixed speed or variable speed operation (and the consequent variable influence of the ventilation);
- mechanical vibration;
- type of convertor for motor speed control (see IEC 146);
- in fluence of the harmonic spectrum of the voltage and/or current feeding the motor (when it is supplied from a static convertor) on the temperature rise;
- method of starting and possible influence of the inrush current on the operation of other users, taking also into account possible special considerations stipulated by the supply authority;
- variation of counter torque load with time and speed;
- influence of loads with large inertia;
- influence of constant torque or constant power operation; and
- possible need of inductive relators between motor and convertor.

17. Accessories and lighting

17.1 Accessories

Where the machine or its associated equipment is provided with outlets to be used for accessory equipment (e.g. hand-held power tools, test equipment), the following conditions shall apply:

- the nominal supply voltage and current shall not exceed 250 V a.c. and 16 A;
- the outlets should comply with EN 60309-1. Where this is not possible, they should be clearly marked with the voltage and current ratings;
- a provision to ensure the continuity of the protective bonding circuit shall be provided (exception see 6.3 and 6.4);

2) Sequence of operation
3) frequency of inspection
4) frequency and method of functional testing
5) guidance on the adjustment, maintenance and repair, particularly of the protective devices and circuits; and
6) parts list and in particular spare parts

g) a description(including interconnection diagrams) of the safeguards, interacting functions, and interlocking of guards with hazardous movements, particularly with interacting installations; and

h) a description of the safeguarding means and methods where the primary safeguards are suspended(e.g. manual programming, program verification)

19.3 Requirements applicable to all documentation

The documents shall be prepared in accordance with IEC 1082-1 and the requirements of 19.4 to 19.10

The item designation system shall be in accordance with the requirements of IEC 740. For large, complex installations, the method in 8.1 of IEC 750 should be used, in which item designation blocks 1 and 3 combined, identify any item, whereas block 2 gives supplementary information on the location of the item where necessary.

For referencing of the different documents, the supplier select one of the following methods:
- each of the documents shall carry as a cross-reference the document numbers of all other documents belonging to the electrical equipment; or
- all documents shall be listed with document numbers and titles in a drawing to document list.

The first method shall be used only where the documentation consists of a small number of documents (e.g. less than five)

19.4 Basic information

The technical documentation shall contain, as a minimum, information on the following:
- normal operating conditions of the electrical equipment, including the expected conditions of the electrical supply and, where appropriate, the physical environment ;
- handling, transportation, and storage; and
- inappropriate use of the equipment.

This information may be presented as a separate document or as part of the installation or operation documentation.

The documentation should also contain, where appropriate, information regarding load and peak starting currents and permitted voltage drops. This information should be contained in either the system or circuit diagrams.

19.5 Installation diagram

The installation diagram shall give all information necessary for thw preliminary work for setting up the machine. In complex cases, it may be necessary to refer to the assembly drawings for details.

The recommended position, type and cross-sectional areas, of the supply cables to be installed on site shall be clearly indicated.

The data necessary for choosing the type, characteristics rated currents and setting, of the overcurrent protective devices to be installed at the origin of the electrical supply cables shall be started.

The size, type and purpose of ducts, cable trays or cable supports between the machine and the associated equipment that are to be provided by the user shall be detailed.

The drawing shall indicate where space is required for the removal or servicing of the electrical equipment.

Where it is appropriate an interconnection diagram or table shall be provided. This diagram or table shall give full information about all external connections. Where the electrical equipment is intended to operate from alternative electrical supplies, the interconnections required for the use of alternative supplies.

19.6 System(block)diagram

Where it is necessary to facilitate the understanding of the principles of operation, a system diagram shall be provided. A block diagram symbolically represents the electrical equipment together with its functional interrelationships without necessarily showing all the interconnections.

Function diagrams may be used either as part of, or in addition to, the block diagram.
NOTE 2 – Examples of function diagrams can be found in Section 2 of IEC 1082-1.

19.7 Circuit diagrams

Where a system diagram does not sufficiently detail the elements of the electrical equipment , a circuit diagram(s) shall be furnished. These diagram shall show the electrical circuits on the machine and its associated electrical equipment. Any graphical symbols not shown in IEC 617 shall be separately shown and described on the diagram and supporting documents. The symbols and identification of components and devices shall be consistent throughout all documents and on the machine.

The diagrams shall be in accordance with IEC 1082-1.

Where appropriate, a terminal function diagram showing the terminals for interface connection and the function of the control system shall be provided. This diagram may be used in conjunction with the circuit diagrams for simplification. The terminal function diagram should contain a reference to the detailed circuit diagram of each unit.

Switch symbols shall be shown of the electro mechanical diagrams with all utilities turn off(e.g. electric power, air, water, lubricant) and with the machine and its electrical equipment in the normal starting condition.

Conductors shall be identified in accordance with 15.2.

Circuit shall be shown in such a way as to facilitate the understanding of their function as well as maintenance and fault location.

Characteristics relating to the function of the control device and components, which are not evident from their symbolic representation, shall be included on the diagrams adjacent to the symbol or referenced to a footnote.

19.8 OPERATING MANUAL

The technical documentation shall contain an operating manual detailing proper procedures for set-up and use of the equipment. Particular attention should be given to the safety measures provided and to foreseen improper methods of operation.

Where the operation of the equipment can be programed, detailed information shall be provided on methods of programming, equipment required, program verification, and additional safety procedures where required.

19.9 MATINTENANCE MANUAL

The technical documentation shall be contain a maintenance manual detailing proper procedures for adjustment, servicing and preventive inspection, and repair. Recommendations on maintenance/service records should be part of this manual. Where methods for verification of proper operation are provided (e.g. software testing program s) their use shall be detailed.

19.10 PARTS LIST

The part list shall include, as a minium, information necessary for ordering spare or replacement parts(e.g. components, devices, software, test equipment, technical documentation) required for preventive or corrective maintenance including those which are recommended to be held in stock by the user of the equipment.
This parts list shall show for each item:

- the item designation used in the documentation ;
- its type designation ;
- the supplier and alternative sources where available; and
- the quantity of items with the same item designation.

20. TESTING

20.1 GENERAL

When the electrical equipment is fully connected to the machine, the following tests shall be performed:

- continuity of the protective bonding circuit (see 20.2)
- insulation resistance tests (see 20.3)
- voltage tests (see 20.4)
- protection against residual voltage (see 20.5)
- electromagnetic tests (see20.6)
- functional tests (see20.7)

When the electrical equipment is modified, the requirements stated in 20.8 shall apply.

20.2 Continuity of the protective bonding circuit

The protective bonding circuit shall be visually inspected for compliance with clause 8 and a check for tightness of the connection of the protection conductors shall be made.

In addition, the continuity of the protective bonding circuit shall be verified by injecting current at least 10A at 50Hz derived from a PELV source for a period of at least 10 s.
The test shall be made between the PE terminal (see5.2) and the various points that are part to the protective bonding circuit.

The measured voltage between the PE terminal and the point of test shall not exceed the values given in table 7.

Table 7 : Verification of the continuity of the protective bonding circuit

Minium effective protective conductor Cross-sectional area of the branch under Test (mm2)	Maximum measured voltage drop(V)
1,0	3,3
1,5	2,6
2,5	1,9
4,0	1,4
> 6,0	1,0

20.3 Insulation resistance tests

The insulation resistance measured at 500 V d.c between the power circuit conductors and the protective bonding circuit shall be not less than 1 M Ohm

20.4 Voltage tests

The insulation equipment shall withstand a test voltage applied for a period of at least 1s between the connectors of all circuits, excluding those intended to operate at below PELV voltages, and the protective bonding circuit.

The test voltage shall:

- have a value of twice the rated supply voltage of the equipment or 1000V whichever is the greater;
- be at a frequency of 50Hz; and
- be supplied from a transformer with a minimum rating of 500VA.

Components which are not rated to withstand this test shall be disconnected during testing.

20.5 Protection against residual voltages

Tests shall be performed to ensure compliance with 6.2.3.

20.6 Electromagnetic compatibility tests

The tests shall be carried out in accordance with IEC 801. The levels of interference used shall be selected in accordance with the environment in which the machine is intended to be used.

It is recognized that with large or complex machines(e.g. several machines working together in a coordinated manner)the tests cannot be carried out on the complete system. In such cases, these tests may be made on the appropriate control subassemblies of the system, prior to integrating system.

20. 7 Functional tests

The functions of electrical equipment, particularly those related to safety and safeguarding. shall be tested.

20.8 Restarting

Where a portion of the machine and its associated equipment is changed or modified. that portion shall be retested in accordance with 20.2 and 20.7

Calculation of Minimum Safety Distance for the Positioning of Safety Devices

0. Purpose

This standard, based on the European Standard EN 999, specifies the calculation of minimum safety distance of protection devices in machinery, according to Article 34-2 of the Industrial Safety and Health Act, Article 59-3 of the Enforcement Decree of the Industrial Safety and Health Act, and Article 4 of the Safety Certification Regulation for Machinery and Equipment (Notification No. 2003-15 of the Ministry of Labor).

1. Scope

1.1 This standard applies to the positioning of protection devices that operates by detecting the movement of the human body or a part of it, and that should be correctly positioned to work effectively, which include:

(1) electro-sensitive protection devices (including those used to initiate the operation of a machine);
(2) pressure-sensitive mats and floors; and
(3) hold-to-run controls (including two-hand control devices).

1.2 Exceptions

(1) Protection against the risks from mechanical hazards arising form the ejection of solid or fluid materials, and non-mechanical hazards such as toxic emissions or radiation, are not covered by this standard.
(2) This standard does not apply to the protection devices that can be moved, without tools, nearer to the danger zone than the calculated distance using this standard (e.g. pendant two-hand control devices).

2. Normative references

(1) EN 292-1, *Safety of machinery - Basic concepts, general principles for design - Part 1: Basic terminology, methodology.*
(2) EN 292-2, *Safety of machinery - Basic concepts, general principles for design - Part 2: Technical principles and specifications.*
(3) EN 294, *Safety of machinery - Safety distance to prevent danger zones being reached by the upper limbs.*
(4) EN 574, *Safety of machinery - Two-hand control devices - Functional aspects -*

Principles for design.

(5) EN 61496-1, *Safety of machinery - Electro-sensitive protective equipment - General requirements and tests.*

(6) EN 60204-1, *Safety of machinery - Electrical equipment of machines - General requirements. (KOSHA CODE E-11-98)*

3. Definitions

3.1 Actuation (of a protection device): Physical initiation of a protection device when detecting the movement of the human body or a part of the body.

3.2 Operation (of a safety device): Transmission of a signal from a protection device to stop the machine or to eliminate the risk.

3.3 Overall response time: Time taken from the actuation of a protection device to the cessation of hazardous motion or the elimination of the risks. It is calculated using the following formula:

$$T = t_1 + t_2$$

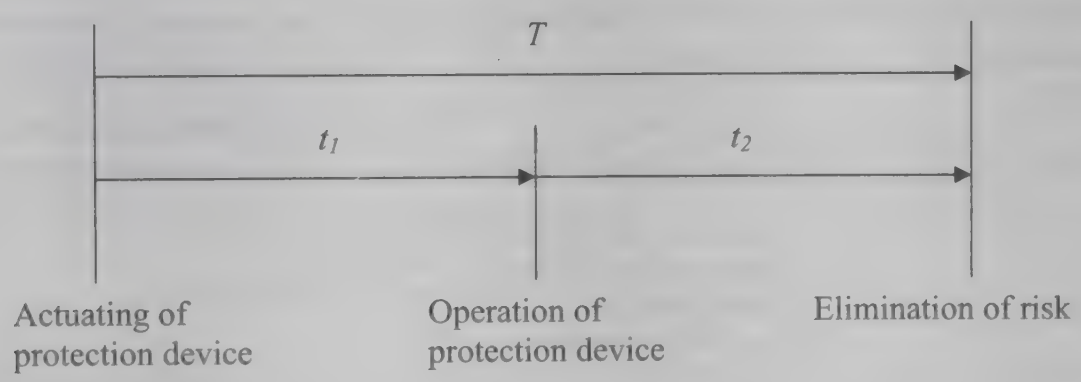


Figure 1. Relationship between t_1 and t_2

3.4 Object detection capability (ODC): Capability of a protection device to detect the human body or an object intruding the danger zone.

0. Methodology

4.1 Figure 2 shows how to determine the correct position of protection devices according to this standard, which is summarized as follows:

(1) Identify the hazards and assess the risks.

(2) When the machine has a specifically applicable standard, select one of the protection devices allowed by the machine-specific standard. Use either the safety distance specified in the machine-specific standard or that calculated using this standard.

(3) When the machine does not have a specifically applicable standard, select an appropriate protection device in accordance with the essential safety and health requirements or any relevant standards. Use formula in this standard to calculate the minimum distance for the danger zone.

(4) Incorporate the distance in the machine design.

(5) Install a protection device in such a way that every approach to the danger zone be detected. Determine the position of the protection device so that the human body between the danger zone and the protection device can always be detected.

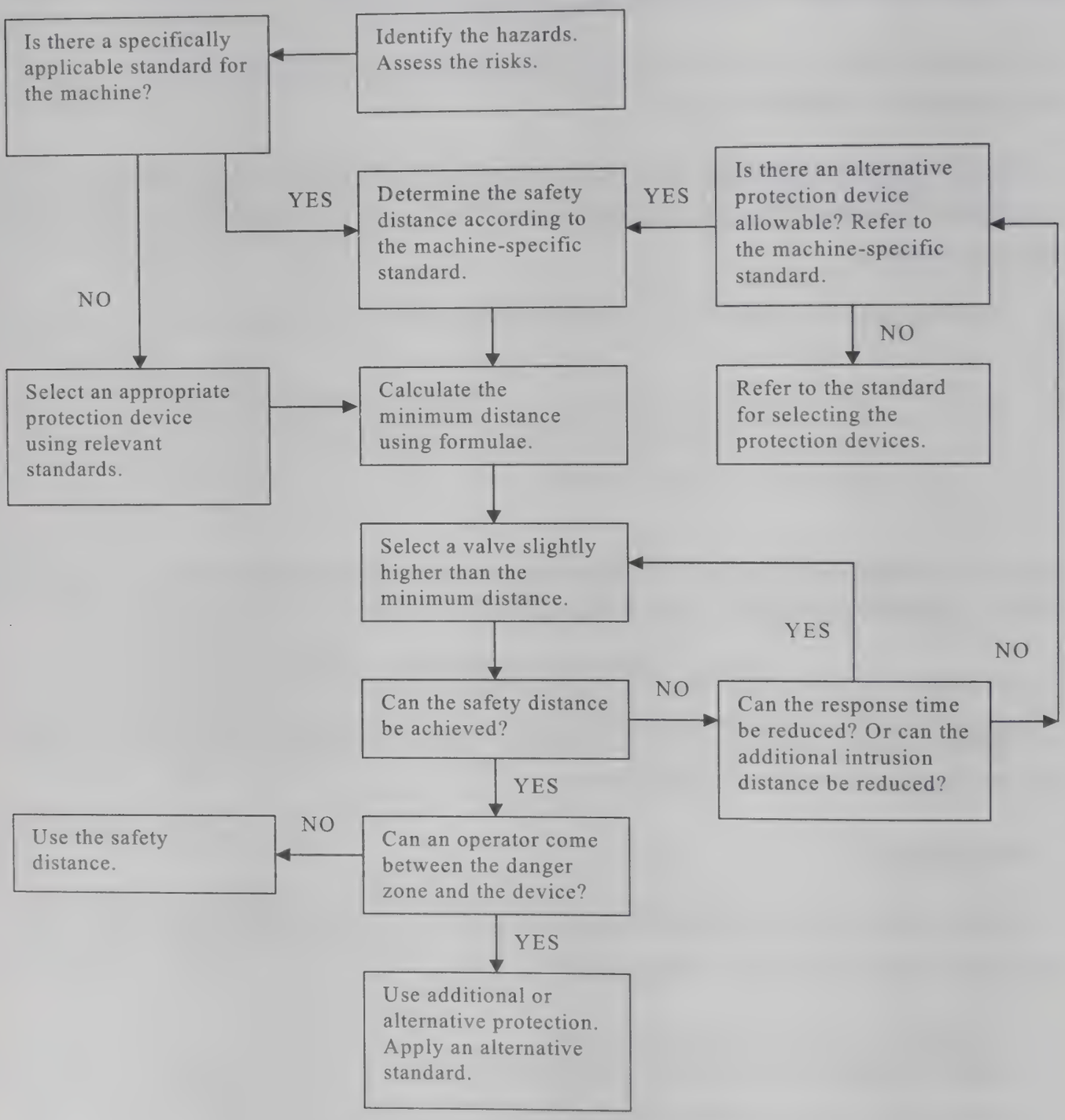


Figure 2. Schematic of methodolog

5. General formula for the calculation of minimum safety distances

(1) The minimum safety distance from the danger zone is given by:

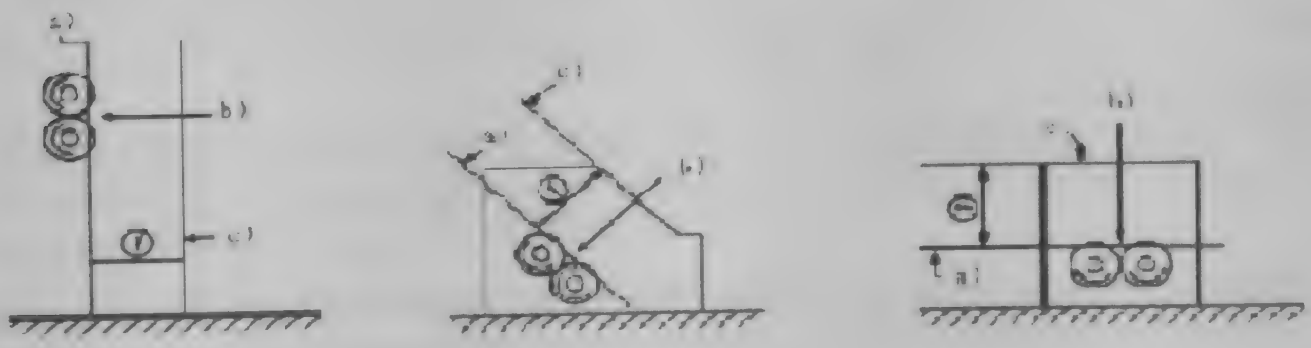
$$S = K \times T + C \qquad (1)$$

where S is the minimum safety distance (mm), i.e. the distance from the danger zone to the detection point, line, or plane; K is the approach speed constant (mm/s), derived from the data on approach speeds of the human body or a part of the body; T is the overall response time (ms); and C is an additional intrusion distance toward the danger zone prior to actuation of the protection device.

(2) For a special machine, select the minimum safety distance higher than that calculated using formula.

6. Electro-sensitive protection devices used only as a trip device or a part of it

(1) When the machine has a specifically applicable standard, select and use the electro-sensitive protection device in accordance with the machine-specific standard.
(2) When the machine does not have a specifically applicable standard, undertake a risk assessment to select an appropriate protection device. Use the machine-specific standard to calculate the safety distance.
(3) The cases to be considered include:
- Normal approach (e.g. vertical curtain) - Parallel approach (e.g. horizontal curtain)- Fixed or movable type - Angled approach



① Safety distance, S
a) Closest danger zone
b) Approach direction
c) Detection range of opto-electronic curtain

Figure 3. Three examples of normal approach

(4) If it is foreseeable to any gaps adjacent to or within the detection zone will allow access to the danger zone, the actions below should be taken:

- Lower the ODC given; - Use an approach interval measurement as a conceptive ODC;
- Install an additional protection to prevent undetected approach.

(5) The size of the access opening in a fixed guard shall comply with the standard for calculating the safety distance (see EN 294).

6.1 Direction of approach normal to the detection zone

6.1.1 Electro-sensitive protection devices with a maximum ODC of 40mm diameter

(1) To protect a person over 14 years old, the safety distance from the danger zone to the detection plane shall not be less than that calculated using formula (2).

$$S = K \times T + C \text{ (see 5.1)} \quad (1)$$

where

K = 2,000 mm/s;
C = 8(d − 14mm), but not less than 0; and
d is the ODC (mm), and it follows

$$S = 2000 \times T + 8(d - 14) \quad (2)$$

(2) Formula (2) applies to all minimum distances of S up to and including 500 mm. The minimum value of S shall not be less than 100 mm.

(3) If S is found to be greater than 500 mm using formula (2), then formula (3) can be used. In this case the minimum value of S shall not be less than 500 mm.

$$S = K \times T + C \text{ (see 5.1)} \quad (1)$$

where

K = 1,600 mm/s; and
C = 8(d − 14mm), and it follows

$$S = 1600 \times T + 8(d - 14) \quad (3)$$

(4) If approach to the danger zone through over the electro-sensitive protection device, the height of the uppermost light beam shall be 1,800 mm or above, or a protection, like a fixed guard, should be installed to prevent such approach.

(5) To protect a person less than 14 years old, use formula (4) to calculate the safety distance.

$$S = K \times T + C \text{ (see 5.1)} \quad (1)$$

where

K = 2,000 mm/s; and
C = 8(d − 5mm), but not less than 0, and it follows

$$S = 2000 \times T + 8(d - 5) \quad (4)$$

6.1.2 Electro-sensitive protection devices used for initiation of machine operation

This type of protection device shall have an OCT equal to or less than 30 mm, formula (5) shall apply, and the minimum safety distance shall be greater than 150 mm.

$$S = K \times T + C \text{ (see 5.1)} \quad (1)$$

where

K = 2,000 mm/s; and
C = 8(d − 14mm), but not less than 0, and it follows

$$S = 2000 \times T \quad (5)$$

6.1.3 Electro-sensitive protection devices with a maximum ODC greater than 40mm and less than or equal to 70 mm

(1) This type of protection device will not detect intrusion of the hands and therefore shall only be used where the risk assessment indicates that detection of intrusion of the hands is not necessary.
(2) The minimum safety distance from the danger zone to the detection zone varies in part according to the body part to be detected and shall be calculated using formula (6).

$$S = K \times T + C \text{ (see 5.1)} \quad (1)$$

where

K = 1,600 mm/s; and
C = 1,200 mm − 0.4H, where H is the height of the uppermost light beam, and it follows that

$$S = 1600 \times T + (1200 - 0.4H) \quad (6)$$

(3) If there is the risk of inadvertent approach to the danger zone, the height of the uppermost light beam shall be 900 mm or above, while that of the lowest light beam shall be 300 mm or below.
(4) Where it is foreseeable that a person less than 14 years old will approach to the danger zone inadvertently, the height of the lowest light beam shall be 200 mm or below.

6.1.4 Multiple separate beams

(1) Since the human body or a part of the body intruding the danger zone is not always detected, conduct a risk assessment for all of the approach cases as shown below, and then apply an appropriate protection according to the results of the risk assessment:
- reaching below the lowest beam; - reaching over the top beam; - reaching through between the two beams; - bodily access by passing between the two beams; and
- access by bending one's back to avoid the overhead beam and stepping over the bottom beam.

(2) If the risk assessment indicates that multiple separate beams are appropriate, use formula (6) to determine the safety distance (see 6.1.3).
(3) Table 1 shows the heights of 2, 3, and 4 beams.

Table 1. Heights of the light beams by its number

Number of beams	Heights above the reference plane (mm)
4	300, 600, 900, 1200
3	300, 700, 1100
2	400, 900

6.1.5 Single height beams

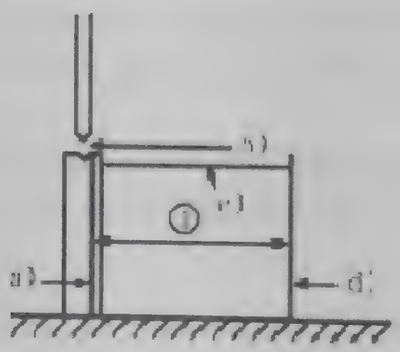
(1) These beams have only been considered when they are used parallel to the ground and the beam is broken by a person's body in the upright position.
(2) Install the beam considering the human body or an object getting over or passing below it.
(3) If the risk assessment shows that the single height beam is appropriate, use formula (7) to calculate the safety distance:

$$S = 1600 \times T + 1200 \quad (6)$$

(4) To prevent the human body or an object from passing below the light beam, install the device at the height of 750 mm from the reference plane.

6.2 Direction of approach parallel to the detection zone

This section describes how to determine the minimum safety distance in the case of a parallel approach, as shown in Figure 4.



① Safety distance, *S*
a) Closest danger zone
b) Approach direction
c) Detection range of opto-electronic curtain
d) Furthest detection plane

Figure 4. Parallel approach

(1) The minimum safety distance from the danger zone to the uppermost light beam depends on the body part to be detected and the detection capability of the protection device, and is given by formula (6).

(2) For this type of protection device the height H of the detection zone shall not be greater than 1,000 mm. However, if the height is greater than 300 mm (200 mm for a person less than 14 years old), there is a risk of inadvertent undetected access beneath the detection zone. Therefore, it is necessary to carry out a risk assessment to install an appropriate protection.

(3) The height of the detection zone is determined considering the maximum allowable ODC, and the minimum allowable height of the detection zone is given by formula (8):

$$H = 15(d_{max} - 40) \tag{8}$$

where H is the height (mm) of the detection zone and $d_{max}$is the maximum allowable ODC (mm).

(4) For a given height of the detection zone, the corresponding maximum allowable ODC is given by formula (9):

$$d_{max} = H/15 + 40 \tag{9}$$

6.3 Dual position beam device

(1) When the detection zone can be readily converted to a position either normal or parallel to the direction of approach, the maximum distances for both the directions of approach shall be applied.

(2) The axis of the rotation of the detection zone shall be at the point where both the normal and parallel detection can be made. However, the last beam is not necessarily required.

(3) When in position normal to the direction of approach (vertical detection zone), the minimum distance S shall be calculated using formula (2) up to ≤500 mm. If S is found to be greater than 500 mm using formula (2), then formula (3) may be used but with a minimum distance of 500 mm.

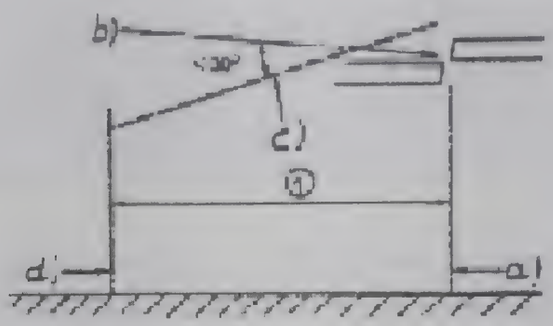
(4) When in position parallel to the direction of approach (horizontal detection zone), the minimum distance S shall be calculated using formulae (6), (8), and (9) up to a maximum height of 1,000 mm.

6.4 Direction of approach angled to the detection zone

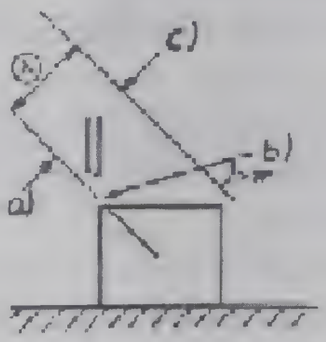
(1) If the angle of approach to the detection zone is within ±5° of the designed angle, it is not considered as an angled approach. In this case, use the formulae defined in Section 6.1-6.3.

(2) For detection zones which are positioned at angles greater than ±5° to the direction of approach, the account shall be taken of the risks associated with the foreseeable methods of approach and the most appropriate formula used.

(3) Foreseeable angles of approach greater than 30° and less than 30° should be considered normal and parallel approaches, respectively.



I) Approach greater than 30°



II) Approach less than 30°

① Safety distance, S
a) Closest danger zone
b) Approach direction
c) Detection range of opto-electronic curtain
d) Furthest detection plane

Figure 5. Angles of approach

(4) When angled approach detection zones are considered as parallel approach, then formula (8) shall apply to the lowest beam or the beam closest to the reference plane (see H2 in Figure 6).

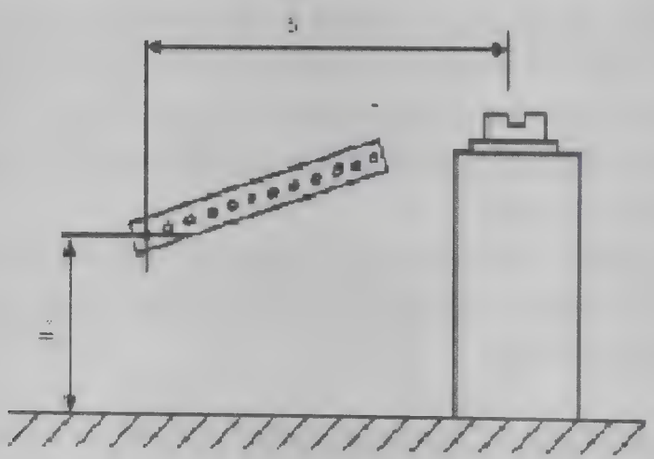


Figure 6. Angled beams

(5) In the case of parallel approach, the formula to derive the minimum safety distance shall apply to the beam furthest from the danger zone. This beam may be used up to a maximum height of the detection zone of 1,000 mm.

7. Methods of calculating the minimum distances for ground level trip devices

(1) Select and use the ground level trip device actuated by the feet in accordance with its specifically applicable standard, if any. If such a machine-specific standard is not available, conduct a risk assessment and then use the device determined according to the results of the risk assessment.
(2) Note that if the risk assessment shows a high risk of serious injury, the minimum safety distance calculated according to this standard may not provide enough protection.
(3) If the speed of approach to the danger zone is higher than walking speed or there is a risk of undetected approach to the danger zone, the minimum safety distance calculated according to this standard is not suitable for ground level trip devices.

7.1 Pressure sensitive mats and floors

(1) The width of the type of mat should be at least 750 mm or above.
(2) The minimum safety distance is given by formula (6) (see 6.1.3):

$$S = 1600 \times T + (1200 - 0.4H) \quad (6)$$

where S is the horizontal minimum safety distance from the danger zone to the furthest detection point, and $H$is the height from the reference plane.

7.1.1 Floor-mounting safety mats

The minimum safety distance for floor-mounting safety mats is given by formula (10):

$$S = 1600 \times T + 1200 \quad (10)$$

7.1.2 Step-mounting safety mats

If the trip device is mounted on a step or raised platform, the minimum safety distance may be reduced by 0.4H, where H is the height (mm) of the step.

8. Hold-to-run controls

8.1 Two-hand control devices

(1) The minimum safety distance from the danger zone to the nearest actuator is given by formula (11).

$$S = K \times T + C \text{ (see 5.1)} \quad (1)$$

where

K = 1,600 mm/s; and
C = 250 mm, and it follows that

$$S = 1600 \times T + 250 \quad (11)$$

(2) If the risk of intrusion of the human body or a part of the body toward the danger zone is eliminated while the actuator is being operated, e.g. by adequate shrouding, then C may be zero, with a minimum allowable distance for S of 100 mm.

8.2 Single acting hold-to-run controls

(1) This type of control is not applicable to the case where a risk is minimized using motion restriction, "jog" control, or speed reduction.

(2) The minimum safety distance from a danger zone to the nearest device is given by formula (12).

$$S = K \times T + C \text{ (see 5.1)} \quad (1)$$

where

K = 1,600 mm/s; and
C = 1,800 mm, and it follows that

$$S = 1600 \times T + 1{,}800 \quad (12)$$

(3) If the risk of intrusion of the human body or a part of the body toward the danger zone is eliminated while the actuator is being operated, e.g. by adequate shrouding, then C may be zero, with a minimum allowable distance for S of 100 mm.

9. Combined protection devices

If two or more protection devices are combined to protect approaches to the danger zone, the minimum safety distance is calculated using each formula for the devices.

10. Examples

(1) The following examples are just informative, but do not mean that the protection selected here is suitable for a specific machine.

(2) If a machine has a specifically applicable standard, follow the machine-specific standard. If not, conduct a risk assessment and use a protection selected according to the results of the risk assessment.

10.1 Example 1

A machine has a stopping time of 60 ms (t2). It is fitted with a vertical electro-sensitive protection device having a detection capability of 30 mm and a response time of 30 ms (t1). Calculate the minimum safety distance.

In formula (2):

$$S = 2000 \times T + 8(d - 14) \quad (2)$$

where S is the minimum distance (mm) from the mold to the curtain; T is the overall response

time of (60 + 30)ms = 90 mm; and d = 30mm.

Then:

$$S = 2000 \text{ mm/s} \times 0.09 \text{ s} + 8(30 - 14) \text{ mm}$$
$$S = 308 \text{ mm}$$

10.2 Example 2

A dual position detection zone is required for a machine with a table height of 1,000 mm. Because there is an allowance of 15 mm between the table and the light beam, the height of the table is set to 985 mm. The overall response time T is 150 ms, and the detection capability of the curtain d is≤40 mm. Calculate the minimum safety distance.

Vertical application (see Figure 7)

In formula (2):

$$S = 2000 \times T + 8(d - 14) \quad (2)$$

where

$T = 150$ ms
$d \leq 40$ mm,

$$S = 2000 \text{ mm/s} \times 0.15 \text{ s} + 8(40 - 14) \text{ mm}$$
$$S = 3{,}000 \text{ mm} + 208 \text{ mm}$$
$$S = 508 \text{ mm (Valid because not greater than 650 mm)}$$

Horizontal direction (see Figure 7)

In formula (8):

$$S = 1600 \times T + (1200 - 0.4H) \quad (8)$$

where

(1200 mm − 0.4*H*) is not less than 985 mm.

Then:

$$S = 1600 \text{ mm/s} \times 0.15 \text{ s} + (1200 - 0.4 \times 985) \text{ mm}$$
$$S = 240 \text{ mm} + 1{,}200 \text{ mm} - 394 \text{ mm}$$
$$S = 1{,}046 \text{ mm}$$

The point of rotation will therefore be at a horizontal distance of 508 mm from the danger zone.
Thus, the minimum safety distance of the detection zone is (1046 − 508) mm = 538 mm. This result is based on the assumption that top-down approach to a danger zone is not allowed when a vertical electro-sensitive protection device is installed.

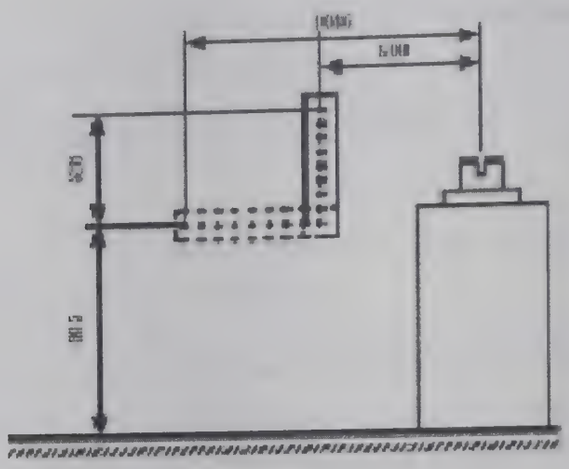


Figure 7. Dual position beam device

10.3 Examples comparing different devices

10.3.1 Example 3A

Inadvertent access to the danger zone of an automated machine system is detected by active opto-electronic protection device. The risk assessment indicates that the risk of serious injury is low and a multiple separate beam device would be appropriate. A three-beam device is selected.

The stopping time of the machine systems is 950 ms and the response time of the protection device is 35 ms. Calculate the minimum safety distance.

From the Table 1, the beams should be set at 300, 700, and 1,100 mm from the floor. The minimum safety distance is given by formula (6):

$$S = 1600 \times T + (1200 - 0.4H) \quad (6)$$

For T=1 s (approximately) and H=1,100 mm,

S = 1600 mm/s × 1 s + (1200 − 0.4×1100) mm S = 1600 mm + (1200 − 400) mm S = 2360 mm

10.3.2 Example 3B

The same machine as in Example 3A will be equipped with a floor mounted pressure sensitive safety mat instead of a three-beam device. Calculate the minimum safety distance.

The minimum safety distance is given by formula (6):

$$S = 1600 \times T + (1200 - 0.4H) \quad (6)$$

Because the mat is laid on the floor, H is 0, and thus

$$S = 1600 \text{ mm/s} \times 1 \text{ s} + (1200 - 0.4 \times 0) \text{ mm S} = 1600 \text{ mm} + 1200 \text{ mm } S = 2800 \text{ mm}$$

This minimum safety distance is longer by 440 mm than that obtained in Example 3A. Thus, an operator can take a single stride to the danger zone before the safety mat operates. A safety mat of 750 mm in width shall be installed from the reference line of the minimum safety distance to the danger zone, in order to prevent an operator from going over it without being detected.

10.4 Example 4

A pressure sensitive safety mat will be installed to prevent approaches to the danger zone while the machine is running. The overall response time of both the safety mat and the machine is 0.5 s. Calculate the minimum safety device.

The minimum safety distance is given by formula (10):

$$S = 1600 \times T + 1200 \quad (10)$$

For T=0.5s

$$S = 1600 \text{ mm/s} \times 0.5 \text{ s} + 1200$$
$$S = 800 \text{ mm} + 1200 \text{ mm}$$
$$S = 2000 \text{ mm}$$

The minimum safety distance from the danger zone to the furthest detection point is thus 2 m.

ANNEX A

Laboratory measurement of the speed of a moving hand for positioning protection devices

The speed of hands is measured the ideals conditions, using a power press simulator equipped with a mold made of soft materials like rubber or expandable poly-styrene. The measurement should be carried out in a ballistic way: that is, a hand shall start to a target, but not return to the start position. The measurement needs a large target, and the hand measured shall move on a spatial surface.

The method of measurement is divided into three groups:

- Group
A hand moves on a straight route between the start and end points. The hand to be measured shall be moving at both the start and end points.

- Group 2
A hand moves on a straight route between the start and end points. The hand to be measured shall be stopped at the start point, but be moving at the end point.

- Group 3
A hand moves on a non-straight route between the start and end points. The hand to be measured shall be stopped at the start point, but be moving at the end point.

The maximum speed is found when the hand in Group 1 moves a short distance (200-300 mm).

The average speed of men's hands was 4.4 m/s. For a longer distance (500-600 mm), however, it was lowered to 2.4-2.8 m/s.

The speed of the hand in Group 2 is typically lower by 10% than that in Group 1. However, the two groups have similar distance of movement.

If a hand moved near an obstacle, like in Group 3, its average speed is lower than that in Group 2, so that such a case is not covered here.

Men under 30 years old showed the highest speed.

With respect to the position of protection devices (100-1000 mm), the relationship between the distance and the hand speed is:

$$v = 2s^{-0.53} \quad \text{(A1)}$$

In the range of 200mm or below, the formula gives too high hand speed.

Formula shows the maximum speed of a hand is given at the shortest distance.
When the overall response time is short, a protection device is positioned at a short distance (see Section 5.1). Under this condition, other factors rather than the hand speed should be taken into account. Some of them are associated with the type of safety device, while others with the type of machine.

The type of protection device covered by this standard is best used to protect the risk of being caught or shearing between two sliding surfaces. A typical example of this risk is a power press. A worker may be injured when his or her hand is caught between the substrate and mold of a power press. If the overall response time of the press is short, the gap between the substrate and the mold should be slightly larger than the thickness of fingers.

No reference is known about the speed of a hand moving through a slot. However, a report described a test of the movement between rectangular objects, which is located all round the human body. It shows that the speed of the movement depends on S/W, where S and W is the distance between the objects and the size of an object in the direction of movement, respectively. Below a critical point, the speed of elastic movement is lowered due to visual feedback that controls the movement. In spite of the result, it is reasonable to assume that the movement in the test can be compared with that of a hand. Therefore, the gap between the substrate and mold should be larger that the thickness of fingers, and it is impossible to obtain the speed of an elastically moving hand, so that the speed given by formula A1 can be said overestimated.

Another reason is that the speed of a hand at a normal work situation is lower than that specified in this standard. When a machine makes an error, an operator should tense the arm muscle to reach the highest speed. Therefore, an operator can approach to a danger zone at a normal speed of operation. The speed calculated according to this standard shows it well.

For electro-sensitive safety systems, the additional components shall apply to plane invasion before its operation. In fact, the calculation for these components is based on the assumption that the hand, keeping horizontal direction, moves straightly at a right angle to the curtain face, with its palm facing down. As the position of a hand is not determined considering the factors, it makes a different situation from reality. For this type of device, safety factor should be added. A more general reason is that a machine equipped with this type of safety device has a very fast stroke time of 1s. This time is several times higher than the average response time of a human body to a visible stimulus in a test under the assumption that there is no response to all errors.

Therefore, the reasons said above shows that an additional measure should be taken even though the hand speed calculated according to this standard is lower than that measured by a test. It shows that accidents were prevented by the protection device installed under the assumption that the hand speed is 1.6 m/s. The most important consideration is that a safety device should work in a reliable way.

ANNEX B

Walking speeds and stride lengths

The positioning of a device that is activated by a person walking into the detection zone, e.g. by stepping into a pressure sensitive mat, is affected by speed of approach and stride length.

The walking speed and stride length depend on the physical and anthropometrics data of the population.

Speed of approach

This standard is based on the assumption that a worker approaches at the speed that is considered not related to the distance across the length specified in this standard.

Stride length

Available research data has shown that the 95th percentile of two strides (i.e. starting and finishing with the same foot) measured from heel contact at walking speed is approximately 1,900 mm. By dividing by 2 and subtracting the 5th percentile shoe length, this gives a stride length of 700 mm. If it is assumed that an allowance has to be made, for example, between the detection zone and the stride length of, e.g. 50 mm, this gives a minimum width of 750 mm for the detection zone.

Concept and Design Principles of Emergency Stop Equipment

0. Purposes

According to the Article 34-2, Industrial Safety and Health Law and the Paragraph 1, Article 124 of Safety Certification Regulation, this standard is to specify design principles for emergency stop equipment for machinery, based on the European Norms(EN2418), in achieving safety in the design of machinery.

1. Scope of application

This standard specifies design principles for emergency stop equipment for machinery. No account is taken of the nature of the energy source. A functional demarcation of the emergency stop equipment's shown in figure 1. Figure 2 illustrates the location of this equipment in machinery.

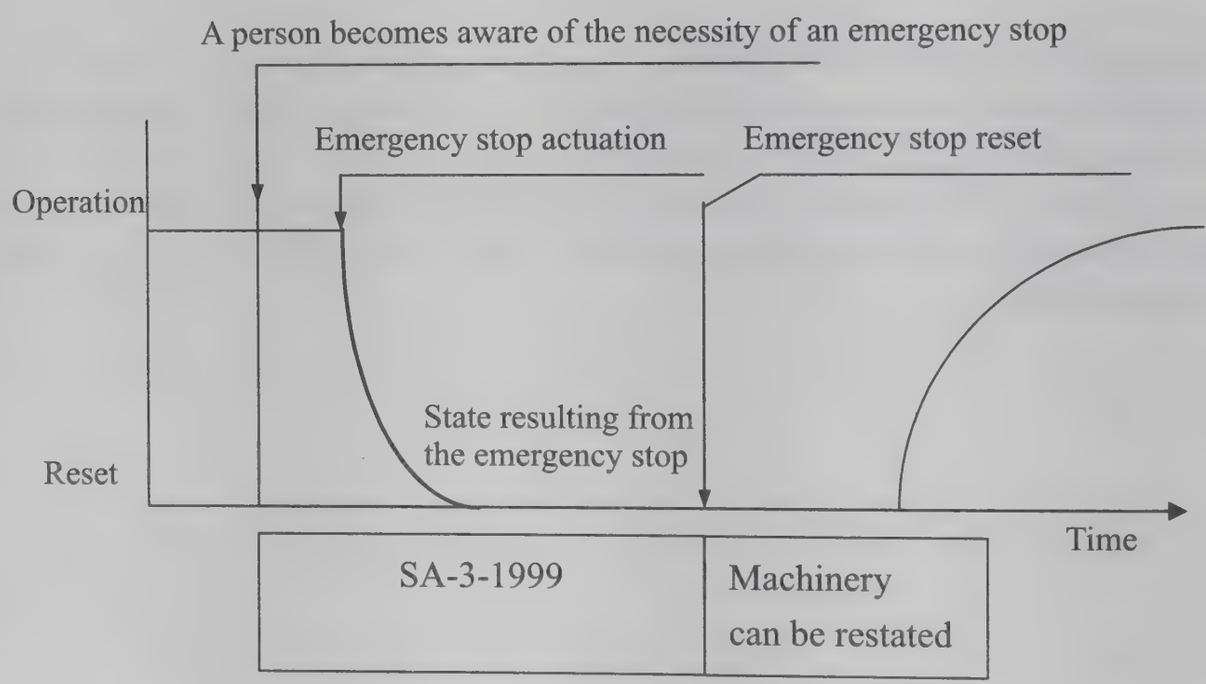


Figure1. Functional aspects of the field of application of SA-3-1999

2. References standards

(1) EN 292-1: Safety of machinery – Basic concepts – general principles for design – Part 1: Basic terminology, methodology

(2) EN 292-2: Safety of machinery – Basic concepts – General principles for design – Part 2: Technical principles and specifications

(3) EN 60204-1(KOSHA CODE E-11-98) : Technical code about the installation of electrical equipment of industrial machinery and.

3. Definitions

For the purposes of this standard, the following definitions apply.

3.1. Emergency stop (function)

Emergency stop function shall has the following capabilities.

(1) It shall avert arising or reduce existing hazards to persons, damage to machinery or to work in progress.
(2) It shall be initiated by a single human action when the normal stopping g function is in adequate for this purpose.

Hazards for the purpose of this standard are those which may arise from:

(1) functional irregularities (malfunctioning of the machinery, unacceptable properties of the processed material, human errors…);
(2) normal operation

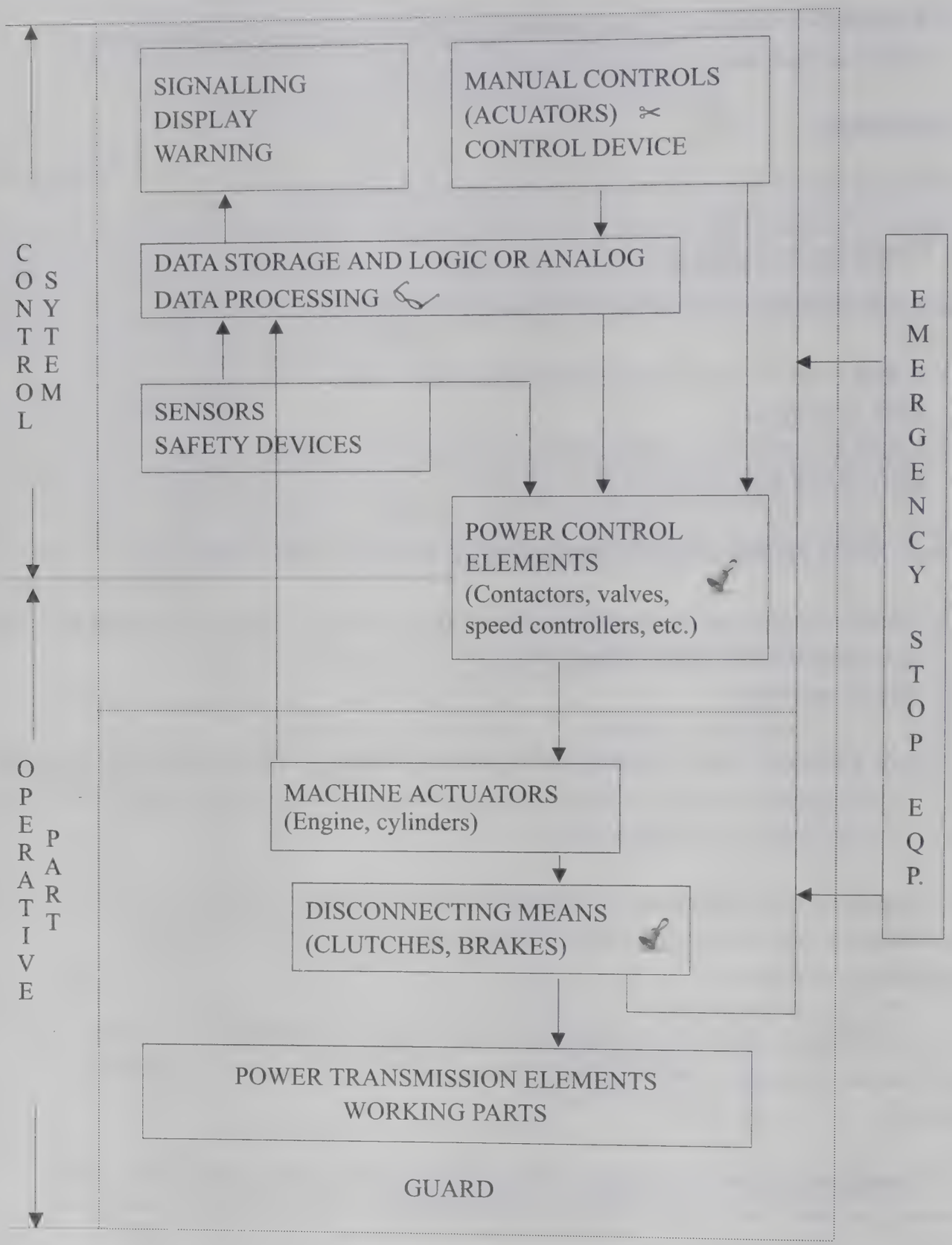
Note. Functions such as reversal or limitation of motion, deflection, shielding, braking, disconnecting, etc. may be part of the emergency stop function. This standard does not deal with these function.

3.2 Emergency stop equipment means arrangement of components intended to achieve the emergency stop function (see figure 2, showing the parts of a machine those components can belong).

3.3 Control device means that component of the emergency stop equipment which generates the emergency stop signal when the associated manual control (actuator) is operated.

3.4 Manual control (actuator) means that component of the control device which, when operated. activates the control device, and is designed to be operated by a person (see 4.4.1).

3.5 Machine actuator means a power mechanism used to effect motion of a machine.



Actuators Control devices Part of the control system intended for emergency stop signal processing Power control elements (contactors, valves or speed controllers), disconnecting means(clutched, etc.) and brakes used for achieving emergency stop, even if they are also used for the normal operation of the machine.

Figure 2. Emergency stop equipment in machinery

4. Safety requirements

4.1 General requirements

4.1.1 The emergency stop function shall be available and operational at all times, regardless of the operating mode.

Note. When emergency stop control devices can be disconnected (e.g. portable teaching pendants) or when machinery can be partially isolated, care shall be taken to avoid confusion between active and inactive control devices.

4.1.2 The control device and its actuator shall apply the principle of positive mechanical action .

Note. A control switch with positive opening operation, is an example of a suitable control device. According to KOSHA CODE E-11-98(clause3.40), positive opening operation (of a contact element) is 'the achievement of contact separation as the direct result of a specified movement of the switch actuator through non-resilient members (e.g. not dependent upon springs)'.

4.1.3 The emergency stop equipment shall neither be used as an alternative to proper safeguarding measures nor as an alternative for automatic safety devices, but it may be used as a back-up measure.

4.1.4 After activation of the actuator, the actuator, the emergency stop equipment shall operate in such a way that the hazard is averted or reduced automatically in the bast possible manner.

Note 1. The statement 'in the best possible manner' includes among other:
- choice of optimal deceleration rate;
- selection of the stop category (see 4.1.5 hereunder), according to the risk assessment.

Note 2. 'Automatically' means that, after activation of the emergency stop actuator, the achievement of the emergency stop function may be the result of a predetermined sequence of internal functions.

4.1.5 The emergency stop shall function as:

(1) either stop category 0, i.e. stopping by: immediate removal of power to the machine actuator(s):or mechanical disconnection (declutching) between the hazardous elements and their machine actuator(s); and, if necessary, braking (uncontrolled stop);
(2) or stop category 1, i.e. a controlled stop with power to the machine actuator(s) available to achieve the stop and then removal of power when the stop is achieved.

4.1.6 The emergency stop equipment shall be designed such that deciding to actuate the emergency stop actuator shall bot require the operator to consider the resultant effects (stopping zone, declaration rate, etc).

4.1.7 The emergency stop command shall override all other commands.

4.1.8 The response of the machine to the emergency stop command shall not generate any additional hazard.

4.1.9 The emergency stop function shall not impair the effectiveness of safety devices or of devices with safety-related functions.

4.1.10 The emergency stop function shall not impair any facilities designed to release trapped persons.

Note. The emergency stop function may include initiation of certain of these facilities.

4.1.11 Any action on the actuator which results in generating the emergency stop command shall also result in the latching-in of the control device so that, when the action on the actuator is discontinued, the emergency stop command be maintained until the control device is reset (unlatched). It shall not be possible for the control device to latch-in without generating the stop command.

Note. In case of a failure in the control device (latching-in means included), the function generating the stop command shall have priority over the latching-in function.

4.1.12 Resetting the control device shall only be possible as the result of a manual action on the control device itself. Resetting the control device shall not by itself cause a restart command. It shall not be possible to restart the machine until all control devices which have been actuated are reset manually, individually and intentionally.

4.1.13 The state the machine is brought into by an emergency stop command shall not alter unintendedly (unexpectedly) during the time the control device is in the actuated condition.

4.2 Specific requirements for electrical equipment See KOSHA CODE E-11-98, paragraphs 10.7).

4.3 Operating condition, environmental influences

The components of the emergency stop equipment shall be selected, assembled and interconnected so that this equipment meets the expected operating conditions and environmental influences. This includes:

(1) consideration of the frequency of operation and the need for periodic testing (especially reliable switching should be foreseen in the case of infrequent operation)
(2) consideration of vibration, shock, temperature, dust, foreign bodies, moisture, corrosive materials, fluids, etc

4.4 Shape, colour and arrangement of emergency stop actuators can be easily actuated by the operators or others who may need to operate them, that many be used include the following types.

(1) mushroom-type push buttons;
(2) wires, ropes, bars;
(3) handles
(4) in specific applications, foot-pedals without protective cover

4.4.2 The emergency stop actuators shall be positioned for easy access and for non-hazardous operation by the operator and others who may need to operate them.

Note. Measures against inadvertent operation should not impair accessibility.

4.4.3 The emergency stop actuators shall be coloured red. As far as a background exists behind the actuator and as far as it is practicable, it shall be coloured yellow.

Note 1. In certain circumstances, it may be useful to provide labels in addition.
Note 2. When using wires or ropes, it can be useful to improve their visibility by using marker flags attached to them.

4.4.4 When machinery is divided in to several 'emergency stop zones', the whole system shall be designed so that it is easy to see which emergency stop actuators correspond to which zones.

4.5 Additional requirements for wires and ropes, when used as actuators

4.5.1 Consideration shall be given to the following requirements.

(1) the amount of deflection necessary for generating the emergency stop signal,
(2) the maximum deflection
(3) the minimum clearance between the wire or the rope and the nearest object in the vicinity,
(4) the force to be applied to the wire or rope in order to actuate the control unit
(5) making wires or ropes visible for the operators (e.g. by use of marker flags).

4.5.2 In event of breaking or disengagement of a wire or a rope, the emergency stop signal shall be generated automatically.

4.5.3 Resetting facilities should be placed so that the whole length of the wire or rope is visible from those resting facilities.

Note. If this is not practicable, the instructions for use should state tat, after actuation and before resetting, the machinery should be inspected along the whole length of the wire or rope in order to detect the reason for activation.

Principles for Ergonomic Design

0. Purpose

This standard, based on the European Standard EN 614-1, specifies the principles for ergonomic design to improve the safety, effectiveness, and efficiency of a work system by assessing ergonomic risks machinery or equipment, to enhance the operators' works and working environment, and to reduce the risks through ergonomic design, according to Article 34-2 of the Industrial Safety and Health Act, Article 59-3 of the Enforcement Decree of the Industrial Safety and Health Act, and Article 4 of the Safety Certification Regulation for Machinery and Equipment (Notification No. 2003-15 of the Ministry of Labor).

1. Scope

This standard establishes the ergonomics principles to be followed during the process of design of work equipment, especially machinery. Although the principles in this standard are oriented towards equipment for occupational use, they are also applicable to equipment for private use.

This standard applies to the interactions between the operator and the work equipment when installing, operating, adjusting, maintaining, cleaning, repairing, or transporting equipment, and outlines the principles to be followed in taking the health and safety of the operator fully into account.

The principles in this standard fully apply to all ranges of individual ability. Information on dimensions will need to be interpreted to suit the intended population.

2. Normative references

(1) EN 292-1, *Safety of machinery - Basic concepts, general principles for design - Part 1: Basic terminology, methodology.*
(2) EN 292-2, *Safety of machinery - Basic concepts, general principles for design - Part 2: Technical principles and specifications.*
(3) EN 547-1, *Safety of machinery - Human body measurements - Part 1: Principles for determining the dimensions required for openings for the whole body access into machinery.*
(4) EN 547-2, *Safety of machinery - Human body measurements - Part 2: Principles for determining the dimensions required for access openings.*
(5) EN 563, *Safety of machinery - Temperatures of touchable surfaces - Ergonomics data to establish temperature limit values for hot surfaces.*
(6) EN 894-1, *Safety of machinery – Ergonomics requirements for the design of displays and control actuators – Part 1: General principles for human interactions with displays and control actuators.*

(7) EN 894-2, *Safety of machinery – Ergonomics requirements for the design of displays and control actuators – Part 2: Displays.*
(8) EN 894-3, *Safety of machinery - Ergonomics requirements for the design of displays and control actuators - Part 3: Control actuators.*
(9) prEN 1005-1, *Safety of machinery - Human physical performance - Part 1: Terms and definitions.*
(10) prEN 1005-2, *Safety of machinery - Human physical performance - Part 2: Manual handling of machinery and component parts of machinery.*
(11) prEN 1005-3, *Safety of machinery - Human physical performance - Part 3: Recommended force limits for machinery operation.*

3. Definitions

3.1 Operator: A person or persons given the task of installing, operating, adjusting, maintaining, cleaning, repairing, or transporting machinery.

3.2 Work task: An activity or activities required to achieve an intended outcome of the work system.

3.3 Work equipment: Machinery, tools, vehicles, devices, furniture, installations, and other components used in the work system.

3.4 Work space: A volume allocated to a person or persons in the work system to complete the work task.

3.5 Work environment: Physical, chemical, biological, organizational, social, and cultural factors surrounding a person in his or her work space.

3.6 Workplace: For a given worker, the combination of work equipment in a work space, surrounded by the work environment, constitutes the workplace of that worker.

3.7 Work system: Comprises one or more persons and work equipment acting together to perform the system task, at the work space, in the work environment, under the conditions imposed by the work tasks.

3.8 Job design: An organization and sequence in time and space of an individual's tasks.

3.9 Work organization: An interaction between people in a work system or work systems.

3.10 Work stress (or External Load): The sum of those external conditions and demands in the work system that acts to disturb a person's physiological and/or psychological state.

3.11 Work strain (or internal reaction): An effect of the work stress upon a person in relation to his or her individual characteristics and abilities.

3.12 Work fatigue: A local or general non-pathological state of work strain, completely reversible with rest.

3.13 Work activity: An activity performed by the worker to achieve the intended outcome of the work system.

3.14 Control actuator: Part of a control actuating system that directly responds to an action of the operator, e.g. by the operator applying pressure.

4. General principles

This section provides the information on some of the ergonomic factors that shall be taken into account when designing a machine. To be able to achieve an efficient, healthy, and safe interaction between operators and work equipment, ergonomics principles as well as technical safety requirements shall be taken into consideration during the design process.

The principles for ergonomic design apply not only to the intended use of work equipment, but also to its installation, adjustment, maintenance, repair, cleaning, and movement.

Design details may influence one another, so any interactions between them should be considered during the design process. For this reason, design focuses essentially on the interaction between the operator and the work environment, and hence the division of functions and labor between the operator and the work environment. The objective is to design the work system to be consistent with human capabilities, limitations and needs. Consequently, this requires a task analysis in the design process.

4.1 Design considering anthropometry and biomechanics

4.1.1 Body dimensions

Work environment shall be designed with proper regard to the body dimensions of the expected population of operators, taking into account:

- body dimensions (static or dynamic dimensions with appropriate clothes and/or personal protective equipment) of adults, children, and the elderly; - range of body dimensions and joint movements; - safety distances; and - dimensions for approach (e.g. for use, maintenance, repair), using anthropometric templates, models and computer-aided models.

The following principles shall be taken into account when designing work equipment:

(1) the operating height or other functional dimensions of equipment shall fit the operator and the type of work being performed, for example by being adjustable;
(2) the type, location and adjustability of any seating provided shall be appropriate to the body dimensions of the operator and to the tasks the operator performs;
(3) sufficient space shall be provided for all the body parts, to allow the task to be performed with good working postures and movements and to facilitate access and changes in posture;
(4) the handles and pedals of equipment shall be appropriate to the functional anatomy of the hand or foot, and the dimensions of the operator population. For hand-held equipment, handles shall be so designed to ensure that the operator is able to grip the equipment correctly and to perform the expected movements; and
(5) frequently used control actuators, grips, and pedals shall be placed within easy reach of the hands and/or feet when the operator is in one of the normal operating positions. Other important control actuators, e.g. emergency stops shall be within easy reach of the operator, whereas less frequently used control actuators shall merely be within reach, unless the task requires otherwise.

When designing work equipment to conform to the expected operator population, at least 5th to 95th percentiles shall be used. Where health and safety aspects are important, wider percentile ranges shall be used, according to the risk assessment, at least to the 1st and/or 99th percentiles. As equipment is designed for use by both men and women, the relevant percentiles for women and for men shall be used.

When determining clearance (such as those for leg room), 95th percentile values shall be used. For reach (e.g. operator reach), 5th percentile values shall be used. Where the work equipment dimensions are adjustable, the range available shall cover the 5th to the 95th percentiles.

NOTE: It is generally better in terms of health, safety, and efficiency, to design to fit as wide a range of the expected operator population as possible. Factors such as sufficient leg room will also ensure operator comfort. Future this standard will contain anthropometrics data on the Korean population, and information on how it should be used. Special consideration will be needed when equipment is being designed for use by disabled people.

4.1.2 Posture

The operator's working posture shall be such that it does not have any injurious effects on the individual.

In the design of work equipment, the following principles shall be taken into account:

(1) awkward postures, e.g. twisting and bending, and prolonged activities leading to body fatigue shall be avoided. Changes in posture shall be possible;
(2) machinery shall preferably enable occasional alternations in the operator's working position between sitting, standing, and walking. Sitting shall generally be preferred to standing as a main working position;
(3) suitable body posture and appropriate support for the body shall be ensured. Supports shall be dimensioned and positioned in order to avoid unbalanced postures. The body posture shall be consistent with the force requirements. Technical aids shall be provided to achieve sufficient leverage and prevent physical overload. To satisfy this requirement for hand-held equipment, it is important that changes in grip during use are avoided by correct positioning of the handles.

4.1.3 Body movements

Work equipment shall be designed to allow the body or parts of the body to move in accordance with their natural paths and rhythms of motion. In particular, the operator shall not be required to make frequent or prolonged movements involving extreme joint angles.

In the design of work equipment, the following principles shall be taken into account:

(1) work equipment shall be constrain the operator to remain immobile when using it;
(2) the design of work equipment shall be such that repetitive movements that lead to impairment, illness, or injury shall be avoided;
(3) movements requiring high precision and accuracy shall require low force for their execution;
(4) aids (such as hoists, rails, stops, etc.) shall be provided for manual handling requiring high precision. The work space shall have adequate dimensions for such aids; and
(5) the application of forces requiring twisting movements or extreme joint positions of the hand arm shall be avoided.

4.1.4 Physical strength

The demands the work equipment makes on the operator's physical strength during work shall be kept to an acceptable level. This level will depend on the weight, shape, size, weight distribution and position of the objects being handled; on the duration and frequency of force application; on the operator's posture (sitting and standing) and movement paths; on the rules and methods of working; and on the specific characteristics of the intended operator populations (e.g. sex, age, health, physical, training).

In the design of work equipment, the following principles shall be taken into account:

(1) where the necessary physical force to be applied cannot be exerted by muscle groups capable of meeting the strength demands, mechanical aids shall be provided.

(2) prolonged static muscle tension (such as that caused by the arms and hands being held aloft) shall be avoided. The weight of hand-held equipment may be an important cause of muscle fatigue when prolonged periods of use are required and its effects should be reduced, e.g. by supporting the equipment on a suspension system;
(3) the application of physical force shall be reduced whenever possible by utilizing the force of gravity or by other measures;
(4) control actuators, grips, handles, and pedals of work equipment shall be designed, selected, and arranged so that the necessary application of physical force is low, unless the application of this general principle has a negative effect on health and safety.
(5) depending on force demands, size, shape, and position of control actuators, uneven loading of the body and limbs shall be avoided. When frequent and long duration use are needed, activation shall be from a seated position; and
(6) with regard to handling requirements, the weight distribution of hand-held equipment shall ensure proper balance.

4.2 Design considering mental ability

Where technical systems have become increasingly automated, the physical demands on the operator have tended to reduce, and the demands on the operator's mental abilities (information perception and processing) have been increased. Work equipment shall be designed to take account of the operator's cognitive capabilities and thereby help to ensure that the health and safety of the operator, and the efficiency of the work system, are not adversely affected.

In particular, the following principles shall be taken into account:

(1) work equipment shall be designed in such a way that its operation does not overload or underload the mental abilities of the intended operators;
(2) any information required for performance of the work task shall be made readily available to the operator.
(3) information shall be presented in such a way that the operator can readily understand and act on it by, e.g. providing a rapid overview of the whole work system as well as providing information concerning detailed parameters; and
(4) where an interactive system is in use, its icons, symbols, and commands shall be consistent in appearance and function.

4.3 Design of displays, signals, and control actuators

4.3.1 Displays and signals

Displays and signals shall be designed, selected, and arranged in a manner compatible with the characteristics of human perception and the task to be performed.

In particular, the following principles shall be taken into account:

(1) the design of displays and signals shall provide for clean and unambiguous perception. This is especially important for emergency displays and signals. Particular attention shall be paid to display intensity, duration of signal, color, shape, size, contract, and prominence against a visual or acoustic background. Alarm signals are more effective when visual and acoustic signals are combined;
(2) to prevent information overload, the numbers and types of displays and signals shall be kept to the minimum necessary for successful work task performance;
(3) the design of displays and signals shall provide the operator with information in a clear and unambiguous form. Unnecessary information shall be avoided;
(4) displays and signals shall be laid out for safe, clear, and rapid orientation and recognition. The priority and frequency of individual pieces of information and the need for feedback in the work task shall be taken into account. The form and content of this feedback shall be specific and well-known to the operator; and
(5) the rate and direction of change in information display shall be compatible with the rate and direction of change in the primary source of that information.

4.3.2 Control actuators

Control actuators and their functions shall be designed, selected, and laid out so that they are compatible with the physiological characteristics (and particularly the movement) of the body parts used to operate them. Speed, precision, and strength requirements shall also be taken into account. The proper design of control actuators can help to avoid human errors and/or minimize their effects.

In particular, the following principles shall be taken into account:

(1) type, design, and layout of control actuators shall correspond to the control task;
(2) control actuators shall be designed and positioned in such a way that the hazards to the operator's health and safety are minimized, taking into account accident hazards, frequency of use, etc. Important control actuators on hand-held equipment shall be positioned so that they can be operated without the operator needing to release the handles;
(3) travel of control actuators and control resistance shall be selected according to the nature of the control task and with regard to the operator's physiological requirements, and shall be based on bio mechanical and anthropometric data.
(4) control actuator function shall be easily identifiable to avoid confusion and be distinguishable from the function of other related or adjacent control actuators;
(5) the control actuator position and its movement, its effect and the related function and or display information shall be mutually compatible;
(6) control actuators, and especially start control actuators, shall be designed, selected, and arranged in such a way to avoid inadvertent operation;

(7) in order to prevent the operator from becoming confused and, consequently, to reduce the number of errors made, the same layout of control actuators and controls shall, as far as possible, be provided when an operator changes from one machine to another of a similar type or function;
(8) the layout of the control panels as well as their shape, location, and interlocking shall be designed to prevent foreseeable human control errors; and
(9) the number of control actuators shall be kept to a minimum consistent with the other requirements. Control actuators shall be laid out so as to ensure safe, unambiguous and task-oriented operation. This shall be done by taking such items as operational sequence, priority, significance, and frequency of individual operations into consideration.

4.4 Interactions with the physical work environment

The design of work equipment shall take account of the effects that any emissions from the equipment my have on the operator or on the work environment (see EN 292-1 and EN 292-2).

4.4.1 Noise and vibration

Emissions of noise and vibration produced during the operation of work equipment shall be reduced to a minimum to avoid health and safety hazards and to ensure the comfort of the operators. Design methods should concentrate on controlling emissions at source to such a degree that the final emission values are low compared to other machines of the same kind.

4.4.2 Thermal emissions

Thermal emissions produced during the operation of work equipment shall be reduced to a minimum through design methods, to avoid health and safety hazards, and to ensure the comfort of the operator.

In particular, the following principles shall be taken into account:

(1) the operator's required physical workload;
(2) the thermal properties of any necessary clothing;
(3) the expected heat load on the operator; and
(4) the temperature of any touchable surfaces (see EN 563).

4.4.3 Illumination

The illumination shall meet the requirements necessary for the operator to perform the work task. If task analysis shows that the ambient lighting is likely to be insufficient, integral lighting shall be provided, e.g. for setting up, adjustment. It shall be designed in such a way

that the operator is not required to adopt an awkward posture. Where the lighting has to be adjusted, the means of adjustment shall be conveniently placed, and shall avoid endangering the operator.

In particular, the following principles shall be taken into account:

(1) flicker shall be avoided;
(2) dazzle or glare shall be avoided;
(3) confusing shadows shall be avoided;
(4) stroboscopic effects shall be avoided;
(5) contrasts shall be adequate for the task; and
(6) color rendering shall be preserved.

4.4.4 Hazardous materials and radiation

Work equipment shall be designed in such a way that any hazardous materials and hazardous radiation present during operation shall be indicated and processed with appropriate devices, in order to avoid exposing the operator to a health hazard.

4.5 Interactions in the work process

The way in which work equipment is to be operated, and the division of functions between the operator and work equipment, are of particular importance, in view of the interactions between these different elements.

In particular, the following principles shall be taken into account:

(1) the different items of work equipment shall be laid out so as to optimize the efficiency of the task, and to ensure the health, safety, and comfort of the operator. For example, the spacing between the different elements of the work equipment shall be sufficient to allow the passage of operations and materials where necessary and lines of sight shall be maintained;
(2) the method of transportation of auxiliary work equipment and materials shall be designed to minimize hazards;
(3) work equipment shall be arranged to avoid hazards to the operator from other equipment in the vicinity;
(4) where a display is linked to the operation of a control actuator. it shall provide clear and unambiguous information where the operator is at the control actuator position; special emphasis should be paid to display-control compatibility;
(5) the operator's working rhythm shall not be linked to the cycle of a semi-automatic or automatic machine or to a transport conveyor. The independence of the operator can be ensured with buffers, feeding devices, robots, etc.;
(6) hand-held equipment shall have the appropriate dimension. weight. balance. and shape

for the anatomy of the hand and shall allow the operator to use natural body motions during its use;

(7) operation by both left and right handed operator shall be considered, particularly for hand-held equipment;

(8) environmental factors of importance for the intended use of machinery, known by the design in advance, shall be taken into account.

5. Application of ergonomics principles to the design process

Using system models, the design of work equipment can be described as a methodological process. Basic tasks, such as setting of objectives, defining requirements, and evaluation, are integrated into this process. Basic engineering and human factors are considered concurrently.

The design process can be considered to occur in for main stages:

(1) development and clarification of specifications;
(2) preparation of a design outline (or outlines);
(3) preparation of detailed design; and
(4) implementation.

In the first stage, the assigned system specification is developed and clarified to establish a list of requirements that can be met. In the second stage, the designer successively refines initial ideas to the point where a choice can be made about which one (or more) to progress further, In the third stage, the designer develops the proposed outlines until a single draft design can be chosen, and detailed design specifications can be obtained. In the last stage, the designer finalizes the design details, and produces the finished design. The operator representatives shall be consulted as early as possible in the design process.

5.1 Ergonomics tasks to be performed

The ergonomics tasks to be performed during the design process shall be in accordance with Table 1. Combinations of these tasks are undertaken at each stage of the design process and the depth of analysis should vary according to the design stage reached.

5.2 Development of design specifications according to ergonomics principles

5.2.1 Development and clarification of specifications

The design of work equipment will be in response to the setting of organizational objectives for the work process, and the work equipment to be designed will be an integral part of that work process. The initial proposals for the solution of the design problem will be evaluated in terms of engineering requirements. To gain the benefits of incorporating ergonomics principles, the operator requirements shall be specified at this early stage of development work (see tasks 1 and 2 in Table 1).

Table 1. Ergonomic works in the design processes

No.	Ergonomics tasks	Description of tasks
1	Establish and clarify the assigned specification.	Establish the part that ergonomics has to play in ensuring the system is efficient, safe, and healthy.
2	Establish the operator population.	Identify the specific characteristics of the operators who will use the equipment.
3	Perform a task analysis.	Establish the division of functions between the operators and the work equipment. Identify the tasks that the operators will have to perform (e.g. operating controls, loading workpieces into machine). Break tasks down into their individual components, to produce a series of events over time for each operator (e.g. observe reading on dial; move control lever to bring reading to required value). Analysis and the study of work situations similar to that being designed, can be useful for this. Operators have a valuable contribution to make at this stage.
4	Identify the ergonomics data required.	Identify by means of task analysis the ergonomics data needed to evaluate a particular design. The example given in task 3 might indicate a need for data on the design of dials (e.g. legibility, accuracy, position); the positioning of dials and controls (allowing the operator to work in an efficient and natural posture); and the design of controls (operator strength limitations, design prevent inadvertent operation). The ergonomics principles to be considered in compiling a list of data requirements are set out in Clause 4.
5	Establish documentation required.	Identify the information to be included in documentation for the operators, e.g. maintenance manuals, operating instructions.
6	Establish training needs.	Consider the results of the task analysis to identify any special training requirements for the operators of the equipment, and any associated implications for safety, cost, and so on (e.g. use of simulator for training, to avoid critical human errors).
7	Choose method of evaluation.	Identify the methods to be used in assessing the data obtained in task 4 against the requirements of the specific design, e.g. use of standards, computer-aided design, simulation of work tasks and work environment.
8	Evaluate the specific design.	Use the methods selected in task 7 to determine whether the ergonomics requirements of the design are within acceptable limits (indicated by the data obtained in task 4).
9	Evaluate the results of the analysis.	Decide whether a reasonable compromise has been reached between the engineering and the ergonomics requirements and, if not, consider repeating some or all of tasks 3 to 7 with a revised design.
10	Evaluate with operators.	Use scale or full-size models of the work equipment or its parts, or simulators, to evaluate the design together with actual operators, and to foresee probable activities. This should include an evaluation of any documentation.
11	Evaluate the results of operator trials and modify.	Re-evaluate the design to incorporate modifications suggested by the operator trials, and repeat tasks 3 to 10 as necessary.

5.2.2 Preparation of outline design

The initial specifications of operator requirements shall take into account the following:

(1) the results of an analysis of the activities of operators on machines to be redesigned, or, in the case of new machines, on similar machines;
(2) the allocation of functions between the work equipment and the operators;
(3) the work tasks which the operators will be expected to perform with the work equipment (in general terms); and
(4) the interactions between the operators and the work equipment.

The specifications shall be evaluated according to the ergonomics principles specified in Clause 4 'General principles'. The results of the evaluation shall be classified according to their degree of acceptability, using, for example, a rating system such as the 3-zone method (see Annex A). When any operator requirements fall outside ergonomically acceptable levels, the design outline shall be revised (see tasks 3 to 9, Table 1). If it is impossible to reach a reasonable compromise between the engineering and the ergonomic requirements that falls within ergonomically acceptable levels, other measures shall be taken, such as operator information on the best possible way to handle the equipment.

5.2.3 Preparation of detailed design

At this stage, the chosen design solution will be developed in depth, and detailed specifications produced (refer to tasks 3 to 9 in Table 1). To ensure that the detailed design takes maximum account of both engineering and operator requirements, reference shall be made to Clause 4 of this standard. Attention shall also be given to such factors as job satisfaction and organizational issues. Task analysis shall be carried out to enable the optimum interface between operator and work equipment to be incorporated in the design.

NOTE: Task analysis allows the designer to determine exactly what will be expected of the operator and to decide what information should be provided for the operator.

The detailed design shall continue to be successively refined until the final design solution can be stated in detailed specifications for the work equipment. When the design solution has been finalized, the necessary documentation for the work equipment shall be drafted. This documentation shall normally include information for the operator on how to use the equipment in a proper ergonomic way.

5.2.4 Implementation

It is recommended that operator trials be carried out to determine whether the design would

benefit from any further refinement (see tasks 10 and 11 in Table 1). Operator trials using scale or full-size models of the work equipment can show any errors in the design, and allow the designer to make improvements based on the experience of operators. Such trials make economic sense also, because the potential need to modify a finished production model is avoided. Similarly, the draft documentation (including the instructions for operators) can also be evaluated in operator trials, with amendments being made on the basis of operator's reactions. When the operator trials have been completed, and any lessons learned for the design for the machine, or if not, for future machines of the same type, the remaining details of the design can be finalized, and the final documentation can be produced.

NOTE: It is recommended that the work equipment and documentation are re-evaluated when they have been in use for a period of time, e.g. one year.

ANNEX A

Guidelines for the use of the 3-zone rating system

This annex describes the 3-zone rating system and its use, including a practical example.

A.0 Introduction

Within the framework of this standard, the task to develop a 3-zone rating system has been given. The objective of the rating system is to establish a common system of design evaluation that will help designers and others to fulfill a risk assessment in a systematic way. The rating system will be helpful to the risk reduction by design.

The 3-zone rating system is a method of classifying ergonomic risk factors in order to simplify the determination of appropriate actions in the design process.

A.1 Rating systems in general

When designing new equipment or when judging the qualities of an existing work equipment it is very useful to arrange the observations systematically. This can be done in many different ways. The basis of systems for classifying work environment factors is defining some precise or some more general criteria. When estimating the properties/qualities of a work environment or a product under design, it is fruitful to arrange the observations in a way that helps the designer to decide what actions should be taken. Rating systems help the designer to arrange observations according to set criteria.

The zones seem appropriate in order to distinguish between design leading to low risk, possible risk (asking for improvement) and high risk (requiring redesign). Existing rating systems can be readily rearranged into a 3-zone rating system.

A.2 The 3-zone rating system

The 3 zones are defined as follows:

(1) Green zone (low risk, recommended): The risk of disease or injury is negligible or is at acceptable low level for the whole operator population in question.

(2) Yellow zone (possible risk, not recommended): There exists a risk of disease or injury that cannot be neglected, for the whole or a part of the operator population in question.

(3) Red zone (high risk, to be avoided): The risk of disease or injury is obvious and exposure cannot be accepted for any part of the operator population in question.

A.3 Use of the 3-zone rating system

As a result of the classification of risk, the following shall be done.

(1) Green zone: No action is needed.

(2) Yellow zone: The risk shall be further estimated, analyzed together with contributing risk factors and followed as soon as possible by redesign. Where redesign is not possible other measures to control the risk shall be taken.

(3) Red zone: Action to low the risk is necessary.

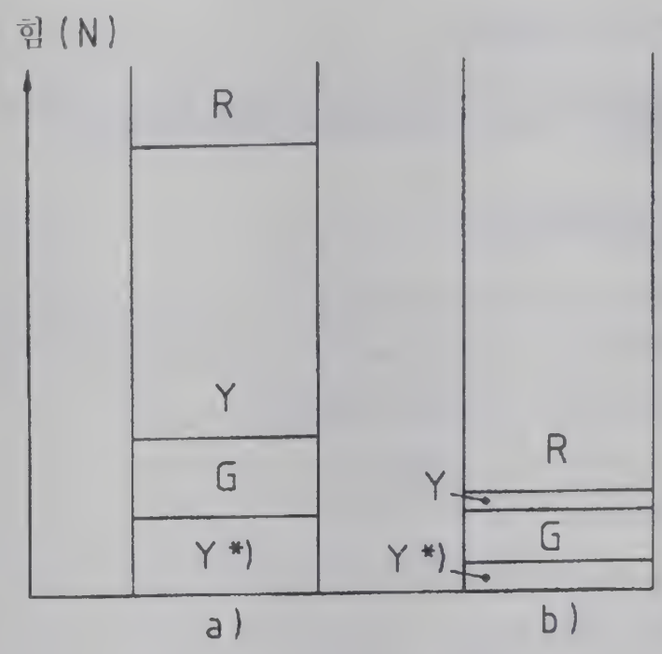
The designer should check the properties of the product against a set of criteria, arranged in accordance with the 3-zone rating system. The result of this assessment will indicate whether the product requires redesigning in order to come into the 'green area', or, if this is not possible, whether some other measures are required to ensure that the product will be used by operators in a way that gives a low risk exposure. Such other measurescould be information on the proper way to use the equipment, instructions that only specially trained operators should use the equipment, or instructions that specify the maximum time for which an individual should use the equipment or other special conditions. Under some circumstances, it may not be possible to produce a design that guarantees a low risk exposure for the operator. It is then essential that warning information be presented to the actual operator(s) in a clear way.

It is also important to keep in mind that the environment in which the product is used may influence the rating in green, yellow, or red zone even in the design stage.

A.4 An example to show the principles of the 3-zone rating system

Pedal actuating:

Figure 1 shows the 3-zone rating system when applied to two different types of pedals. These pedals are shown in Figure A.2.

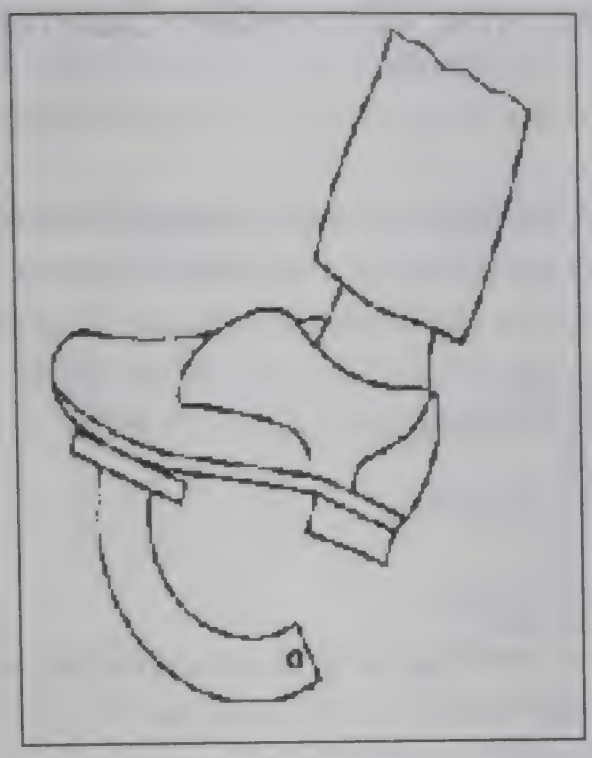


a) Leg actuated pedals
b) Ankle actuated pedals

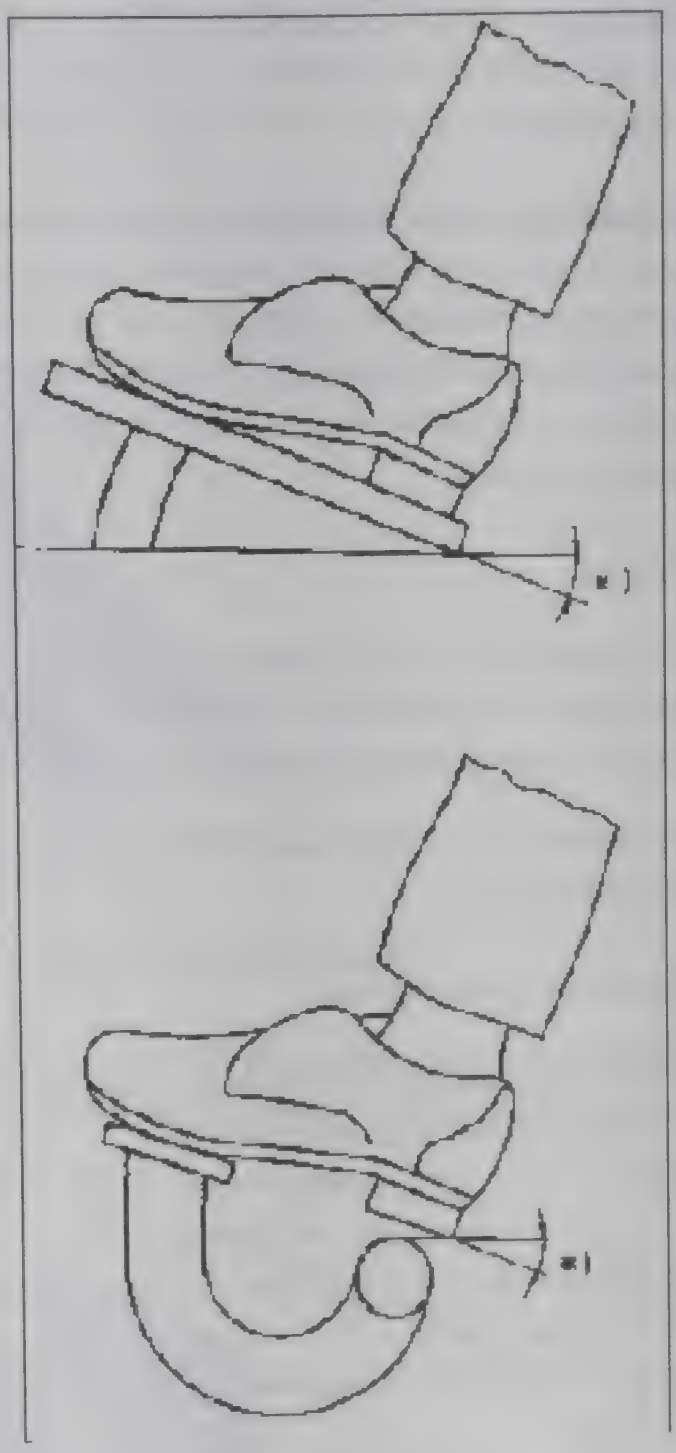
G (Green zone)
Y (Yellow zone)
R (Red zone)

*) Below the green zone there will be a yellow to red zone depending on the weight of the leg/foot. To ensure safety and health the green zone must give the optimal resistance in the pedal to avoid unintended movements.

Figure A.1 Forces for two different types of pedals



a) Leg actuated pedals



a) Ankle actuated pedals

*) 15-20°

Figure A.2 Leg and angle actuated pedals

Design and Construction of Fixed and Movable Guards

1. Purpose

This standard, based on the European Standard EN 953, specifies the requirements for design and construction of fixed and movable guards to protect the operators using machinery or equipment, according to Article 34-2 of the Industrial Safety and Health Act, Article 59-3 of the Enforcement Decree of the Industrial Safety and Health Act, and Article 4 of the Safety Certification Regulation for Machinery and Equipment (Notification No. 2003-15 of the Ministry of Labor).

2. Scope

This standard defines the requirements for the design and construction of guards provided to protect persons from mechanical hazards, and also applies to the methods of minimizing the exposure tonon-mechanical hazards, like noise or radiation, using the guards.

The requirements in this standard are applicable to fixed or movable guards, but do not cover interlocking guards.

3. Normative references

(1) EN 292-1, *Safety of machinery - Basic concepts, general principles for design - Part 1: Basic terminology, methodology.*
(2) EN 292-2, *Safety of machinery - Basic concepts, general principles for design - Part 2: Technical principles and specifications.*
(3) EN 294, *Safety of machinery - Safety distance to prevent danger zones being reached by the upper limbs.*
(4) EN 349, *Safety of machinery - Minimum gaps to avoid crushing of parts of the human body.*
(5) EN 1050, *Safety of machinery – Principles for risk assessment.*

4. Definitions

4.1 Guard: A part of a machine specifically used to provide protection by means of a physical barrier. It may be called casing, cover, screen, door, endorsing guard, etc., depending on its construction.

NOTE 1: A guard may act:
- alone: it is then only effective when it is closed
- in conjunction with an interlocking device with or without guard locking; in this case, protection is ensured whatever the position of the guard.

NOTE 2: "Closed" means "kept in place" for a fixed guard.

4.2 Fixed guard: A guard kept in place either permanently (by welding, etc.) or by means of fasteners (screws, nuts, etc.) making removal/opening impossible without using tools.

4.2.1 Fixed enclosing guard: A guard that prevents access to the danger zone from all sides, as shown in Figure 1.

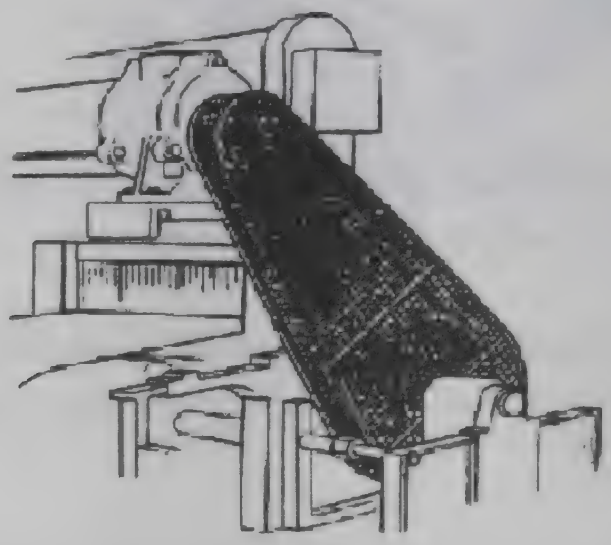


Figure 1. Example of a fixed enclosing guard

4.2.2 Fixed distance guard: A guard that does not completely enclosure a danger zone, but prevents or reduces access by virtue of its dimensions and its distance from the danger zone, e.g. perimeter fence or tunnelguard (see Figure 2 and 3).

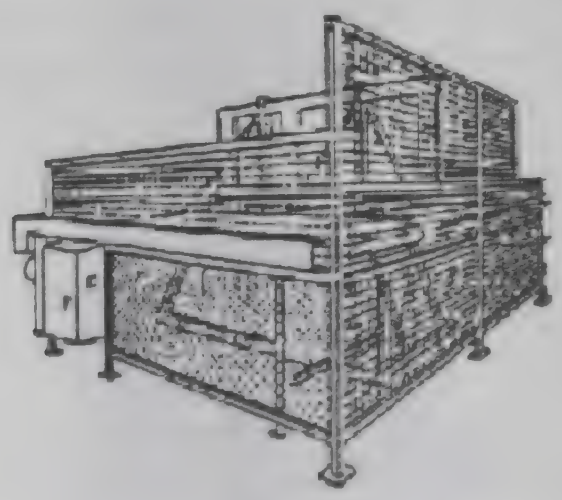


Figure 2. Example of a fixed distance guard

NOTE: This type of guard protects persons passing a danger zone. The control device of a machine is positioned outside of the guard.

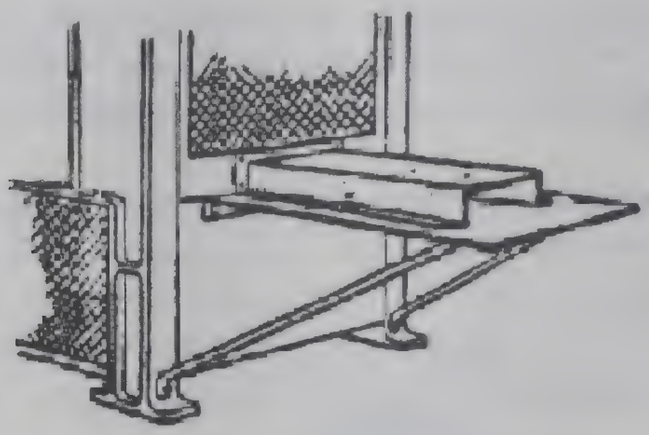


Figure 3. ~Example of a fixed distance guard: tunnel guard that provides protection at machine feed or discharge area

4.3 Movable guard: A guard generally connected by mechanical means (e.g. hinges, slides) to the machine frame or an adjacent fixed element and which can be opened without the use of tools (see 3.22.2 of EN 292-1).

4.3.1 Power operated guard: A movable guard that is operated with the assistance of power from a source other than persons or gravity.

4.3.2 Adjustable guard: A fixed or movable guard that is adjustable as a whole or which incorporates adjustable part(s). The adjustment remains fixed during a particular operation, as shown in Figure 4 (see 3.22.3 of EN292-1).

NOTE: The guard is telescopic to provide ready adjustment to the surface of the workpiece. It is attached to a hinge to permit access to the spindle for drill changing.

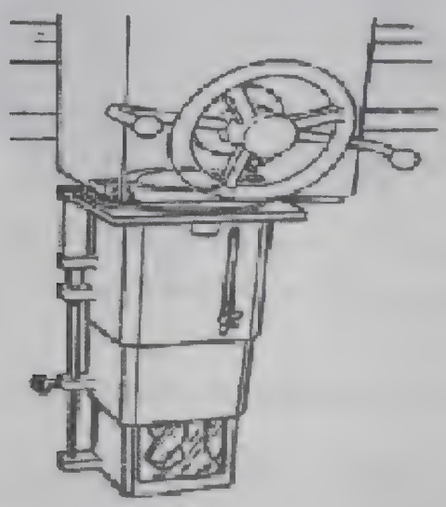


Figure 4. Example of an adjustable guard for a radial or pedestal drilling machine

4.3.3 Self closing guard: A movable guard operated by a machine element (e.g. moving table) or by the workpiece or apart of the machining jig, so that it allows the workpiece (and the jig) to pass and then automatically returns to the closed position as soon as the workpiece has vacated the opening through which it has been allowed to pass (see Figure 5).

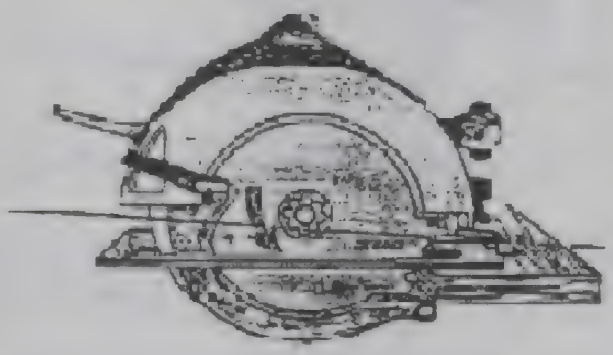
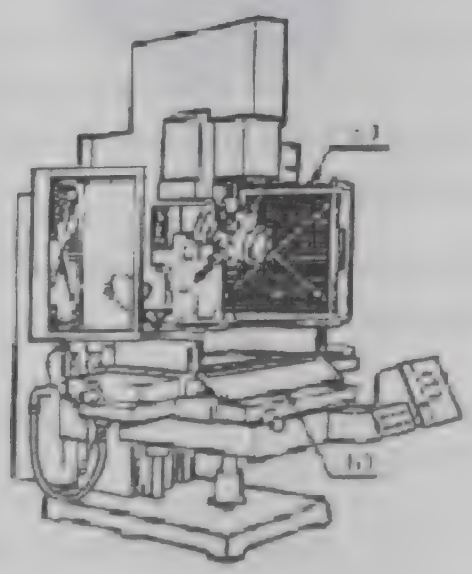


Figure 5. Example of a self closing guard

4.3.4 Interlocking guard: A guard associated with an interlocking device (see 3.23.1 in EN 292-1) so that:

(1) the hazardous machine functions covered by the guard cannot operate until the guard is closed;
(2) if the guard is opened while hazardous machine functions are operating, a stop instruction is given; and
(3) when the guard is closed, the hazardous machine functions covered by the guard can operate, but the closure of the guard does not by itself initiate their operation (see Figure 6 and 7).



a) Interlocking guard
b) Interlocking work area guard

Figure 6. Example of interlocking hinged guards

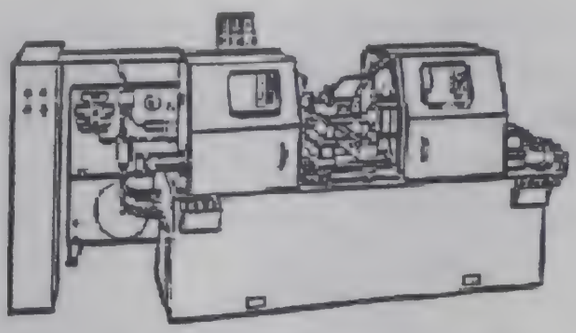
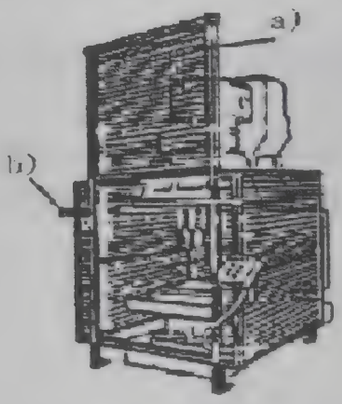


Figure 7. Example of interlocking sliding guards

4.3.5 Interlocking guard with guard locking: A guard associated with an interlocking device and a guard locking device (see 3.23.1 of EN 292-1), as shown in Figure 8, so that:

(1) the hazardous machine functions covered by the guard cannot operate until the guard is closed and locked;
(2) the guard remains closed and locked until the risk of injury from the hazardous machine functions has passed; and
(3) when the guard is closed and locked, the hazardous machine function closed by the guard can operate, but the closure and locking of the guard do not by themselves initiate their operation.

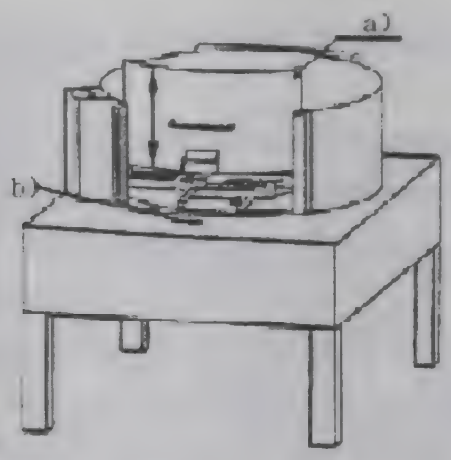


a) Interlocking guard in the open position
b) Solenoid shot bolt

Figure 8. Example of safeguarding of drilling machine using interlocking guards with guard locking and fixed guards

4.3.6 Control guard: A guard associated with an interlocking device and with or without a guard locking device (see 3.23.1 of EN 292-1) so that:

(1) the hazardous machine functions covered by the guard cannot operate until the guard is closed; and
(2) closing the guard initiates operation of the hazardous machine function(s).
NOTE: the use of control guards is subject to certain conditions, as shown in Figure 9 (see 4.2.2.5 in EN 292-2).



a) The sprung protection door is supported when opened.
b) The pin actuates the valve to initiate the machine.

Figure 9. Example of a control guard on a rotary machine

4.3.7 Guard closed position: A guard is closed when it performs the function for which it was designed to protect a person or persons.

4.3.8 Guard open: A guard is open when it does not perform the functions for which it was designed to protect a person or persons.

4.3.9 Tool: An implement such as key or wrench designed to operate a fastener. An improvised implement such as a coin or nail file cannot be considered to be a tool.

4.3.10 Frequency of access: Number of occasion on which access is required or foreseeable within the guarded area per unit of time.

5. Risk assessment

In order to select and design types of guards appropriate to particular machinery, it is important to access the risk arising from the various hazards present at that machinery (see Clause 6 of EN 292-1).

6. Selection of types of guards

6.1 General

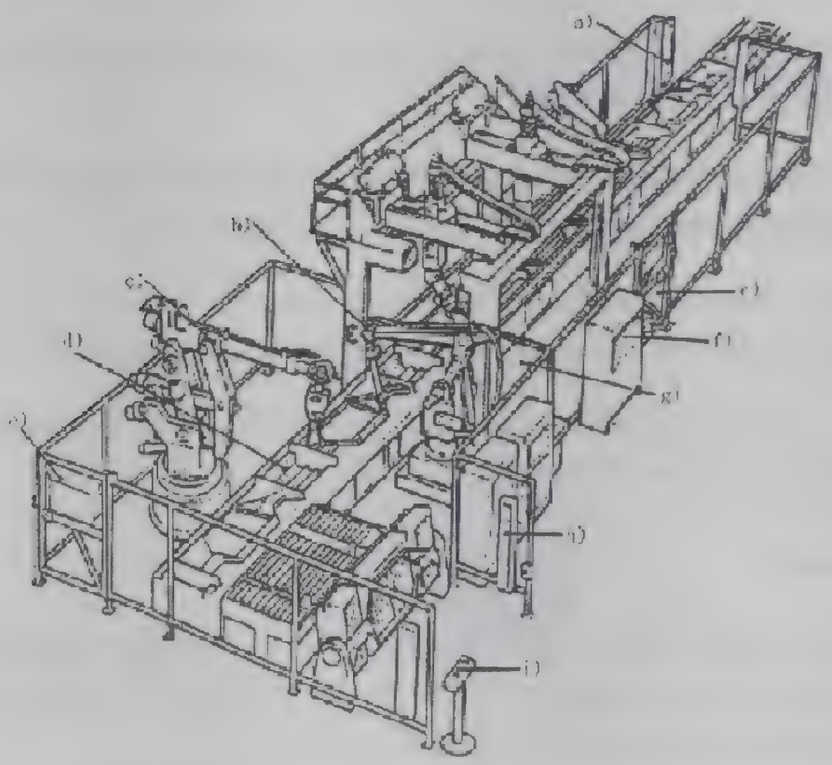
The guard to be used shall be compatible with the functions of the machine, and its manufacturer shall describe the risks, which may be caused by any foreseeable misuse, in the manual (see 3.12 of EN 292-1). To select suitable guards, not only the following items but also the life of the guards shall be taken into account:

(1) the hazards present at the machine (see Clause 4 of EN 292-1);
(2) the probability and foreseeable severity of any injury as indicated by the risk assessment; and
(3) the nature and frequency of access.

6.2 Combination of different guards or of guards with other devices

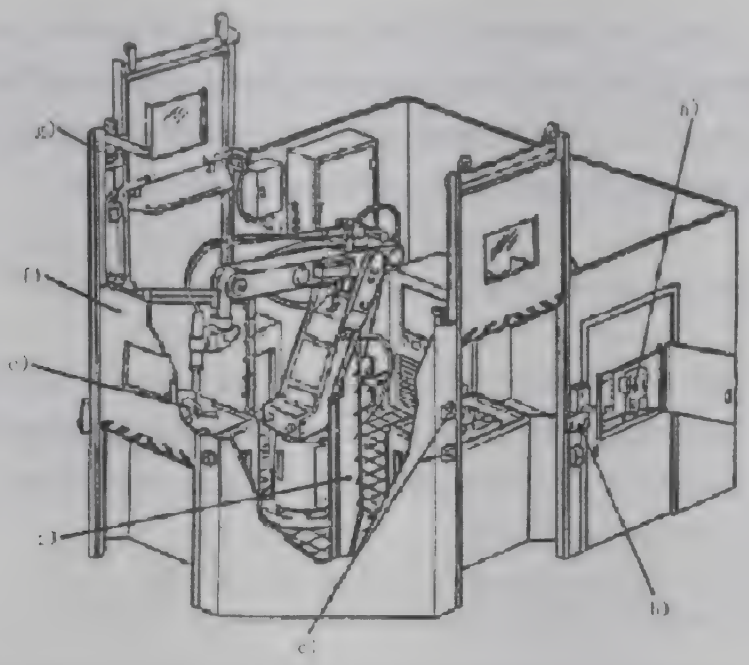
(1) It can be appropriate to use a combination of different types of guard. For example, if a machine has several danger zones and access is required to one of them during the operation phase, the guards can consist of a fixed guard combined with an interlocking movable guard.

(2) In a similar way, a combination of protective devices and guards can sometimes be necessary. For example, where in conjunction with a fixed guard, a mechanical feed device is used to feed work pieces into a machine, (thereby removing the need for access to the danger zone) a trip device (see 3.23.5 of EN 292-1) can be required to protect against a secondary trapping or shearing hazard between the mechanical feed device and the fixed guard (see Figure 10 and 11).



a) Photo-electric safety device interlocked with adjacent devices
b) Robot 1
c) Robot 2
d) Track
e) Interlocking guard
f) Electric cabinet with a locking device
g) Internal fence allowing only sectional access
h) Photo-electronic curtain
i) Two-hand control device

Figure 10. Example 1 of combination of different guards and guards with other protective devices



a) Teach pendant
b) Trapped key system
c) Two-hand control device
d) Screen between stations
e) Welding table
f) Vertically adjustable interlocking guard
g) Shot bolt (guard locking device)

Figure 11. Example 2 of combination of different guards and guards with other protective devices

6.3 Selection of guards according to the nature and frequency for access required

6.3.1 Moving transmission parts

Guards to protect against hazards generated by moving transmission parts (e.g. pulleys, belts, gears, rack and pinions, shafts) shall be either fixed guards (see Figure 1) or movable interlocking guards.

6.3.2 Where access is not required during use

Simple and reliable fixed guards should be used when it is not necessary to access the danger zone when adjusting, learning the operations of, correcting or modifying the process of, or cleaning the machine.

6.3.3 Where access is required for machine setting, process correction or maintenance

(1) A fixed guard should be used if the foreseeable frequency of access is low and its replacement is easy.

(2) A movable guard should be selected if the foreseeable frequency of access is high (e.g. more than once per shift) or if its removal or replacement would be difficult. Movable guards shall be associated with an interlock or an interlock with guard locking, except the case when the risk assessment indicates it is not necessary.

6.3.4 Where access is limited to the non-dangerous area for the work

(1) A movable guard with interlock or with interlock with guard locking should be used. If access is required for a very short working cycle (e.g. an operator should access the work area at every working cycle of an automated press with very short cycle), a power operated movable guard is preferred.
(2) A control guard should be used (see 4.2.2.5 of EN 292-2).

6.3.5 Where access to the danger zone cannot be totally prohibited due to the nature of the operation

For example, a saw blade needs to be partially exposed and the operator have to feed workpieces with hands, the following guards are appropriate:

(1) Self closing guard (see 7.4.6 for special requirements)
(2) Adjustable guard (see 7.4.7 and 4.2.2.4 of EN 292-2)

6.4 Selection of guards according to the location of the hazards

6.4.1 When it is required to limit hazards to a defined zone

Examples of these hazards include emissions, toxic smoke or gas, noise, etc.

The guard selected should be installed so that it completely closes the danger zone. If necessary, movable guards should be used; interlocking guards should be selected, except that the risk assessment indicates it is not required.

6.4.2 When hazards is within the moving range of a machine

Examples of these hazards include a collision, trapping, crushing, shearing, etc.

Guards should be selected from the following in the order of priority given:

(1) Local guards enclosing individual danger zone if the number of danger zones to protect is low. This should permit access to non-mechanical machine parts for maintenance, setting, etc.
(2) A guard enclosing all the danger zones if the number or size of the danger zones is high. In this case, setting and maintenance points should, as far as possible, be located outside

the guarded area.

(3) Partial fixed or fixed distance guard if the use of an enclosing guard is impractical and the number of the danger zones to protect is low.

(4) Fully surrounding fixed distance guard if the use of an enclosing guard is impracticable and the number or size of the danger zone is high.

7. Design of guards

The following requirements for the design of guards shall be account.

7.1 Machine aspects

It is necessary to properly consider foreseeable aspects of the machine environment and operation throughout the foreseeable life of the machine in the design of guards. Inadequate consideration of these aspects can lead to unsafe or inoperable machinery, and can lead persons to defeat the guards provided thus exposing them to greater risk.

7.1.1 Minimization of access to danger zones

To minimize access to danger zones where practicable, guards and machinery shall be so designed as to enable routine adjustments, lubrication and maintenance to be carried out without opening or removing the guards. Where access is required within the guarded area, this shall be as free and unobstructed as practicable. The examples of reason for access include:

- Loading and unloading;
- Tool changing and setting;
- Measurement, gauging, and sampling;
- Process observation;
- Maintenance and repair;- Lubrication;
- Removal of waste material (e.g. scrap, swarf, spillage);
- Obstruction removal;
- Cleaning and hygiene.

7.1.2 Containment of ejected parts

Where there is a foreseeable risk of ejection of parts (e.g. broken tooling, workpiece) from the machine, the guard shall as far as practicable be designed and constructed from appropriate materials selected to contain these.

7.1.3 Containment of hazardous substances

Where there is a foreseeable risk of emission of hazardous substances (e.g. coolant, vapors,

gases, swarf, sparks, hot or molten material, dust) from the machine, the guard shall be designed to contain these as far as practicable.

7.1.4 Extraction

Where there is a foreseeable risk of emission of hazardous fumes, smokes, or dust from the machine or process, the machine shall be equipped with appropriate extraction equipment.

7.1.5 Noise

Where a requirement has been established to reduce machine noise, guards shall be so designed and constructed as to give the required noise reduction as well as protection against the other hazards present t the machine.

7.1.6 Radiation

Where there is a foreseeable risk of exposure to hazardous radiation, guards shall be designed and appropriate materials selected to protect persons from the hazard. Examples include the use of darkened glazing to prevent weld flash or the elimination of openings in a guard around a laser.

7.1.7 Explosion

Where there is a foreseeable risk of explosion, guards shall be designed to contain or dissipate the released energy in a safe manner and direction (e.g. by use of explosion relief panels).

7.2 Human aspects

Reasonably foreseeable aspects of human interaction with machinery shall be given proper consideration in the design of guards.

7.2.1 Safety distances

Guards intended for preventing access to danger zones shall be designed, constructed, and positioned to prevent parts of the body from reaching the danger zones. The safe distance or the access opening shall be in accordance with S2-G-1-1999, Safety Certification Standard – Calculation of minimum safety distance for the positioning of safety devices.

7.2.2 Control of access to the danger zone

As far as practicable movable guards shall be designed and positioned so that during normal operation they prevent persons from accessing the danger zone. However, this does not apply to the case where another measure (e.g. locking device, key interlocking, etc.) is used for the same purpose.

7.2.3 Viewing

To minimize the need to remove them, guards shall be designed and constructed to offer viewing of the process.

7.2.4 Size and weight

Removable sections of guards shall be designed to be of a suitable size and weight to permit ease of handling. Guards which cannot readily be moved or transported by hand shall be provided, or be able to be provided with suitable attachment devices for transport by means of lifting gear, as follows:

- standard lifting appliances with slings, hooks, eye bolts or simply tapped holes for appliance fixing;
- appliances for automatic grabbing with a lifting hook, when securing is not possible from the ground;
- an indication, on the guard itself and on some of its removable parts or in the information for use, of the value of their mass expressed in kilograms (kg); and
- lifting gear and appliances integrated into the guard.

7.2.5 Operating forces

Movable guards or removable sections of guards shall be designed to permit ease of operation.

The observance of ergonomic principles in designing guards contributes to increasing safety by reducing stress and the physical effort of the operator. This improves the performance and reliability of the operation, thereby reducing the probability of errors at all stages of machine use (see 4.9 of EN 292-1). Operating forces can be reduced by the use of devices such as springs, counterbalances or gas struts.

Where guards are power operated they shall not be capable of causing injury (e.g. from contact pressure, force, speed, sharp edges). It is also necessary to use protective devices or other measures to protect persons.

7.2.6 Climbing

Climbing on guards shall as far as practicable be inhibited by design. Consideration shall be given to this possibility in their construction and the selection of materials and shapes. For example, by eliminating horizontal structural members and the horizontal component of mesh fabric from the outside surface of the guard, climbing is made more difficult.

7.2.7 Foreseeable misuse

As far as practicable guards shall be designed to take into account use and reasonably

foreseeable misuse (see 3.12 of EN 292-1).

7.2.8 Aesthetics

As far as practicable guards shall be designed so as to minimize adverse psychological effects.

7.3 Guard aspects

All foreseeable aspects of guard operation shall be given proper consideration at the design stage to ensure that the guard does not create a further hazard.

7.3.1 Crushing or trapping points

Guards shall be designed so as not to cause hazardous crushing or trapping points, with parts of the machine or of other guards.

7.3.2 Durability

Guards shall be designed to perform their function properly throughout the foreseeable life of the machine or provision made from replacement of degradable parts.

7.3.3 Hygiene

Where applicable, guards shall be designed so as not to create hazards to hygiene by trapping items or material, e.g. food particles, stagnant fluids.

7.3.4 Cleaning

Guards used in certain applications, notably for processing of food and pharmaceuticals shall be so designed that they are not only safe to use but can be readily cleaned.

7.3.5 Extrusion of containments

Where there is a requirement for the process, guards shall be designed to exclude containments from the process, e.g. in the food, pharmaceutical, electronic, and related industries.

7.4 Construction and installation of guards

7.4.1 Sharp edges etc

Guards shall be constructed so as not to have exposed shape edges and corners or other hazardous projections.

7.4.2 Integrity of joints

Welded, bonded, or mechanically fastened joints shall be of sufficient strength to suit reasonably foreseeable loading. Where bonding agents are used, these shall be compatible with the process and materials being used. Where mechanical fastening are used, their strength, number and spacing shall be sufficient to ensure the stability and rigidity of the guard.

7.4.3 Removal only by tool

Demountable parts of guards shall only be removable with the aid of a tool (see 4.3.9).

7.4.4 Positive location

Where practicable removable guards shall be unable to remain in place without their fixings.

7.4.5 Positive closing of movable guards

The closed position of movable guards shall be determined positively. The guard shall be held in position against a stop by means of gravity, a spring, catch, guard locking device or other means.

7.4.6 Special requirements for self closing guards

The self closing guard opening shall be limited to no more than that required for the passage of the workpiece. It shall not be possible to lock the guard in its open position. These guards can be used in conjunction with fixed distance guards.

7.4.7 Special requirements for adjustable guards

Adjustable parts shall be such as to enable the opening to be restricted to a minimum consistent with the passage of material, and be easily adjustable without the use of a tool.

7.4.8 Retention of movable guards

Where practicable movable guards shall be attached to the machine or adjacent fixed elements so that they are retained, e.g. by hinges or slides, even when open. Such attachments shall only be removable with the aid of a tool.

7.4.9 Resistance to vibration

Where applicable fastenings can need to be fitted with lock nuts, spring washers, etc. to ensure that they remain attached to the guard.

7.4.10 Noise shielding

The connections of the guard used to shield noise shall be sealed to prevent noise from escaping through the guard.

7.4.11 Captive fastenings

Where practicable guard fastenings shall remain attached to the guard, as this reduces the likelihood of their being lost and not replaced (see Figure 12).

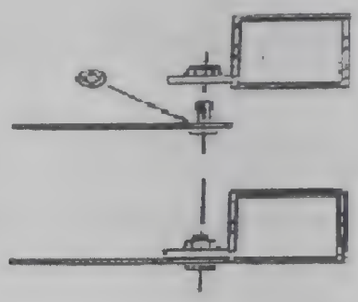


Figure 12. Example of a captive fastening

7.4.12 Warning signs

Where access within the guarded area can expose persons to residual risks, e.g. radiation, appropriate warning signs shall be placed at access points.

8. Selection of materials

The following aspects shall be taken into account when selecting suitable materials for the construction of guards. These properties shall be maintained throughout the foreseeable life of the guard.

8.1 Impact resistance

Guards shall be designed to withstand reasonable foreseeable impacts from parts of machinery, workpiece, broken tooling, ejected solid or fluid matter, impact by the operator, etc. Where guards are fitted with viewing panels, special consideration shall be given to the selection of materials and method of fixing these. Materials shall be selected with properties suited to resist the mass and velocity of the ejected object or material.

8.2 Rigidity

Support posts, guard frames and infill materials shall be selected and arranged to provide a rigid and stable structure and to resist deformation. This is especially important where deformation of material could be detrimental to maintaining safety distances.

8.3 Secure fixing

Guards or parts of guards shall be secured by fixing points of adequate strength, spacing and number to remain secure under any foreseeable loading. Fixing can be by means of mechanical fasteners or clamps, welded or bonded joints or other means suited to the application.

8.4 Reliability of moving parts

Moving parts, e.g. hinges, slides, handles, catches, shall be selected to ensure reliable operation given their foreseeable usage and working environment.

8.5 Containment

Harmful substances, e,g, fluids, swarf, dust, fumes, which can reasonably be foreseen, shall be contained within the guard by suitable impermeable material.

8.6 Resistance to oxidation and corrosion

Materials shall be selected which are resistant to foreseeable oxidation and corrosion, and suitable protective coatings can be helpful to achieving the requirements.

8.7 Chemical resistance

Guards shall be designed to withstand foreseeable chemical damage from manufacturing processes, e.g. cutting oil, cleaning oil, disinfectants, and environmental factors. Suitable protective coatings shall be provided to maintain the chemical resistance of the guards.

8.8 Resistance to microorganisms

Where there is a foreseeable risk to health from bacterial and fungal growth, such as in the food, pharmaceutical and related industries, materials used in the construction of guards shall be selected that inhibit this growth and can be easily cleaned and disinfected.

8.9 Non-toxicity

Materials and finishes used shall be non-toxic in all foreseeable conditions of use and compatible with the process involved especially in food, pharmaceutical and related industries.

8.10 Machine viewing

Where viewing of machine operation is required through the guard, materials shall be selected with suitable properties, e.g. if perforate material or wire mesh is used this should be of

adequate open area and suitable color to permit viewing. Viewing will be enhanced if the perforate material is darker than the area observed.

8.11 Transparency

As far as practicable, materials used for viewing machine operation shall be selected from those that retain their transparency, with age and use. Guards shall designed to make provision for the replacement of degraded materials.

Certain applications can require the selection of materials or combinations of materials that are resistant to abrasion, chemical attack, degradation by ultra violet radiation, dust attraction by static electrical charge, or surface wetting by fluids which impair transparency.

8.12 Stroboscopic effects

Where there is a foreseeable hazard from stroboscopic effect, materials shall be selected which minimize this occurrence.

8.13 Electrostatic properties

Certain application can require the selection of materials that do not retain an electrostatic charge, in order to avoid an accumulation of dust and particles as well as sudden electrical discharge with the associated risks of fire or explosion. Guards can need to be earthed to avoid build up of static charge to a hazardous level.

8.14 Thermal stability

Materials shall be selected which do not degrade, e.g. are not subject to brittle fracture, deform excessively or emit toxic or flammable fumes when exposed to the range of foreseeable temperature variations, or sudden changes in temperatures. Materials selected shall retain their properties in foreseeable climatic and workplace conditions.

8.15 Flammability

Where there is a foreseeable risk of fire, materials selected shall be spark resistant, and fire retardent and shall not absorb or emit flammable fluid, fumes, etc.

8.16 Noise and vibration reduction

Where necessary, materials shall be selected to provide noise and vibration reduction. This can be achieved by means of insulation (putting an acoustic barrier in the path of the noise), and/or absorption (lining guards with appropriate acoustically absorbent materials) or a

combination of both. Guard panels can also need to be suitably damped to minimize effects of resonance that can transmit or amplify noise.

8.17 Radiation protection

In certain applications such as welding or use of lasers, materials shall be selected that protect persons from harmful radiation. For welding applications, this can be by means of a suitably tinted transparent screen that permits viewing but eliminates harmful radiation.

8.18 Color

The color of guards shall be suitably selected to highlight hazards.

9. Verification of the safety requirements for guards

Certain aspects of guard design and construction shall be subject to verification by examination, inspection, testing, or calculation. Where practicable verification shall be carried out with the guard in its working situation.

9.1 Impact strength

Verification can be required for the resistance of guards to impact from persons, parts of tools, high pressure liquids, etc. Before carrying out this verification it is necessary to identify the foreseeable impact hazard to which guard can be subject.

9.2 Safety distances

Verification that guards comply with the required safety distances shall be made (see S2-G-1-1999).

9.3 Containment

Where guards are designed for containment of hazardous substances (see 6.1.3) the performance of this function shall be verified. Where leakage is readily seen, visual inspection can be adequate. Where leakage cannot be seen, e.g. leakage of gas or vapor, and alternative verification method such as air sampling is required.

9.4 Rigidity

Where the maintenance of the functions of guards is essential to the proper operation of the machine the rigidity of guards shall be verified.

9.5 Noise

When a guard is designed to reduce noise, its acoustic performance shall be verified by taking noise readings to check out if the level of noise reduction meets the requirement of the standard.

9.6 Guard operating forces

Where normal usage of a guard involves the application of physical force, e.g. to open movable guards, remove fixed guards, it can be necessary to verify that these forces are not excessive as specified.

9.7 Visibility

Where the maintenance of visibility through the guard is essential to the proper function of the guard this shall be verified under normal operating conditions by means of a visual check.

10. Information for design, construction, and use of guards

The instructions for use shall contain the detailed information on guards and the methods of removing risks from them.

10.1 Design and construction of guards

10.1.1 Risk assessment

Detailed information on the risk assessment of guards shall be provided (see S2-G-5-1999).

10.1.2 Drawings

The drawings of guards shall show the circuit diagrams of associated equipment to be used and the position of warning signs.

10.1.3 Materials

Specifications of the materials used shall be described.

10.1.4 Guard hazards

Information on the hazards of the guards itself, e.g. inflammability of materials, shall be provided.

10.1.5 Implementation data

Information on safety distance, impact resistance, or noise limit, shall be provided to verify the suitability of the guard.

10.1.6 Installation

Instructions shall be supplied for the correct installation of guards and associated equipment.

10.2 Use of guards

10.2.1 Operation

Instructions shall be provided directing the user to the correct operation of the guards, their interlocks, etc. Warning against reasonably foreseeable misuse shall be given.

10.2.2 Removal

Information shall be provided indicating any actions to be taken before guards may be removed safely, e.g. machine power isolation or dissipation of stored energy.

10.2.3 Inspection and maintenance

Details shall be provided of inspections to be carried out and maintenance required for, as follows:

- loss of or damage to any part of the guard, especially where this leads to deterioration of safety performance, e.g. reduction of impact resistance from scratches to glazing materials;
- replacement of wearing parts
- correct operation of interlocks
- degradation of joining or fixing points
- degradation by corrosion, temperature change or chemical attack;
- satisfactory operation and lubrication of moving parts;
- modification of safety distances and aperture sizes; and
- degradation of acoustic performance.

Interlocking Devices Associated with Guards

1. Purpose

This standard, based on the European Standard EN 1088, specifies the principles for design and selection of interlocking devices associated with the guards machinery or equipment, according to Article 34-2 of the Industrial Safety and Health Act, Article 59-3 of the Enforcement Decree of the Industrial Safety and Health Act, and Article 4 of the Safety Certification Regulation for Machinery and Equipment (Notification No. 2003-15 of the Ministry of Labor).

2. Scope

This standard applies to design and selection of interlocking devices associated with guards, regardless of the nature of the energy source.

3. Normative references

(1) EN 292-1, *Safety of machinery - Basic concepts, general principles for design - Part 1: Basic terminology, methodology.*
(2) EN 292-2, *Safety of machinery - Basic concepts, general principles for design - Part 2: Technical principles and specifications.*
(3) EN 294, *Safety of machinery - Safety distance to prevent danger zones being reached by the upper limbs.*
(4) EN 953, *Safety of machinery – Guards – General requirements for the design and construction of fixed and movable guards.*
(5) EN 954-1, *Safety of machinery - Safety-related parts of control systems – Part 1: General principles for design.*
(6) EN 999, *Safety of machinery – The positioning of protective equipment in respect of approach speeds of parts of the human body.*
(7) EN 1037, *Safety of machinery – Prevention of unexpected start-up.*
(8) EN 1050, *Safety of machinery – Principles for risk assessment.*
(9) EN 60204-1, *Safety of machinery - Electrical equipment of machines - General requirements. (KOSHA CODE E-11-98)*
(10) EN 60947-5-1, *Low-voltage switchgear and controlgear - Part 5-1: Control circuit devices and switching elements - Electromechanical control circuit devices.*

4. Definitions

4.1 Interlocking device (interlock): A mechanical, electrical, or other type of device, the purpose of which is to prevent the operation of machine elements under specified conditions (generally as long as a guard is not closed).

4.2 Interlocking guard: A guard associated with an interlocking device, so that: the hazardous

machine functions covered by the guard cannot operate until the guard is closed; if the guard is opened while the hazardous machine functions are operating, a stop instruction is given; when the guard is closed, the hazardous machine functions covered by the guard can operate, but the closure of the guard does not by itself initiate their operation.

4.3 Interlocking guard with guard locking: A guard associated with an interlocking device and a guard locking device, so that: the hazardous machine functions covered by the guard cannot operate until the guard is closed and locked; the guard remainsclosed and locked until the risk of injury from the hazardous machine functions has passes; when the guard is closed and locked, the hazardous machine functions covered by the guard can operate, but the closure and locking of the guard do not by themselves initiate their operation.

4.4 Guard locking device: A device intended to lock a guard in the closed position and linked to the control system so that: the machine cannot operate until the guard is closed and locked; the guard remains locked until the risk has passed.

4.5 Automatic monitoring: A back-up safety function to ensure that a safety measure is initiated if the ability of a component or an element to perform its function is diminished, or if the process conditions are changed in such a way that hazards are generated. Automatic monitoring is divided into 2 categories:

- 'continuous'automatic monitoring, whereby a safety measure is immediately initiated when a failure occurs;
- 'discontinuous' automatic monitoring, whereby a safety measure is initiated during a following machine cycle, if a failure has occurred.

4.6 Positive mode actuation: If a moving mechanical component inevitably moves another component along with it, either by direct contact or via rigid elements, the second component is said to be actuated in the positive mode (or positively) by the first one.

4.7 Positive opening operation of a contact element: Achievement of contact separation as the direct result of a specified movement of the switch actuator through non-resilient members (e.g. not dependent upon springs). (See Chapter 3 Special requirements for control switches with positive opening operation of EN 60947-5-1.)

NOTE: For fluid power, the equivalent concept may be called 'positive mode interruption'.

4.8 Stopping time (time for hazard elimination): Period between the point at which the interlocking device initiates the stop command and the point at which the risk from hazardous machine functions has passed.

4.9 Access time (time for access to a danger zone): Time taken to access the hazardous machine parts after initiation of the stop command by the interlocking device, as calculated on the basis of an approach speed.

5. Operating principles and typical forms of interlocking devices associated with guards

NOTE: Reference is made to the relevant informative annexes where it is considered useful for clearer understanding.

5.1 Interlocking principles

5.1.1 Control interlocking

The stop command from the interlocking device is introduced into the control system so that interruption of the energy supply to the machine actuators, or mechanical disconnection of moving parts from the machine actuators, is triggered by the control system (indirect interruption: level A and B in Figure 1).

5.1.2 Power interlocking

The stop command from the interlocking device directly interrupts the energy supply to the machine actuators or disconnects moving parts from the machine actuators (level C in Figure 1). 'Directly'means that, unlike control interlocking, the control system does not play any intermediate role in the interlocking function.

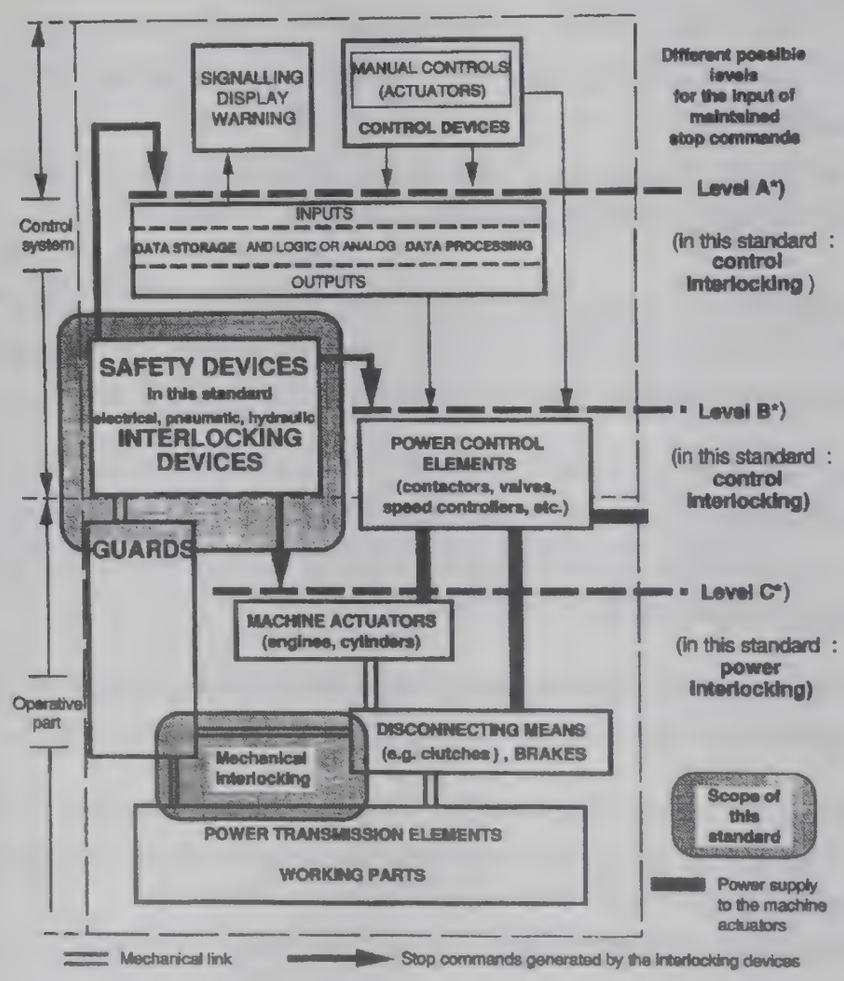


Figure 1. Location of interlocking devices in machinery (based on Annex A of EN 292-1)

5.2 Typical types of interlocking devices

5.2.1 Interlocking device without guard locking (see Table 1 and Figure 3a)

It is always possible to open the guard. As soon as the guard is no longer closed, the interlocking device generates a stop command. As it is possible to start opening the guard during operation of the machine (or of the hazardous machine elements), the function is that of an interlocking device, as defined in paragraph 2-1 of Article 25 of the Safety Certification Regulation. Examples of interlocking devices without guard locking are shown in Annex A, B, F, G, J, K, L.

5.2.2 Interlocking device with guard locking (see Table 1 and Figure 3b)

(1) The guard is held closed by a guard locking device (see 4.4). There are two types of devices:

- those where unlocking the guard can be initiated at any time by the operator (unconditional unlocking: see Table 1 and Figure 3b1). - those where unlocking the guard is possible only if a condition is fulfilled (conditional unlocking: see Table 1 and Figure 3b2).

(2) The guard locking device (see 3.4) can be either an integral part or a separate unit of an interlocking device or an part unit.

(3) In a guard locking device, the part that is intended to lock/unlock the guard can be:

- manually applied, manually released (see Figure N in Annex N);
- spring applied, power released (see Figure 2a);
- power applied, spring released (see Figure 2b);
- power applied, power released (see Figure 2c).

Examples of interlocking devices with guard locking are in Annex C, D, E, H, M, N.

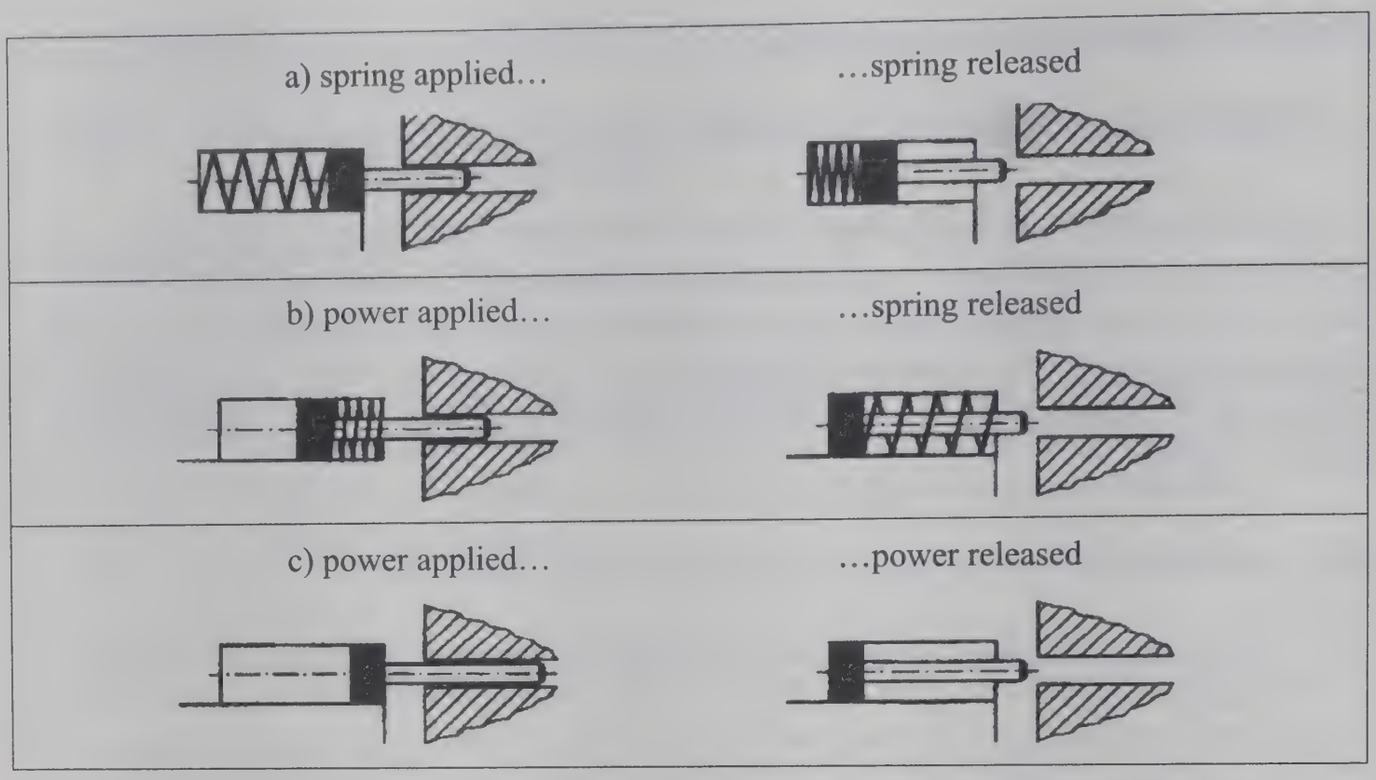
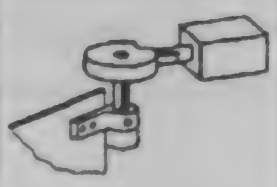
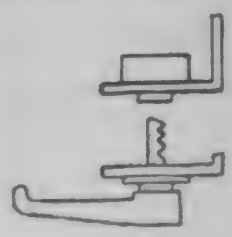
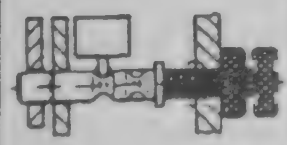
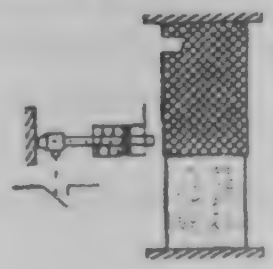


Figure 2. Operating modes of the guard locking device in power-actuated guard locking devices

Table 1. Various aspects of the interlocking devices with and without guard locking

Interlocking devices without guard locking (see 4.2.1 and figure 3a))	**Interlocking devices with guard locking** (see 4.2.2 and figure 3b))		
	Unconditional unlocking (see figure 3b1)) Unlocking the guard can be started at any time by the operator, but the time necessary for the guard to be unlocked is longer than the time necessary for the hazard to disappear	**Conditional unlocking** (see figure 3b2)) Unlocking the guard is made possible only if (or is triggered when) one of the following conditions is fulfilled :	
		- a fixed time**) has elapsed after the stop command has been given;	- disappearance of the hazard has been detected (e.g. zero-speed detection).
Stop command given :			
- at the beginning of the guard opening stroke (the interlocking device is actuated by the guard itself);	- simultaneously with the beginning of the actuation of the lock*) and as a consequence of it;	- shortly after the beginning of the actuation of the guard locking device and as a consequence of it;	- by the operator, or automatically by the control system, then memorized by the interlocking device.
 (see annexes A, G)	 (see annex D)	 (see annex N)	 (see annex M)
Typical examples			

*) Strictly speaking, the guard is unlocked after the beginning of the stop command. Where the hazard disappears "as soon as the stop command is given" (in any case before the guard is unlocked), the function ensured is equivalent to that of an interlocking guard with guard locking.

**) Longer than the time necessary for the hazard to disappear.

Table 2. Technological forms of interlocking devices

Technological forms	Provisions in clauses	Examples in Annexes
Interlocking devices with mechanically actuated detectors: - with cam-operated detectors; - with tongue-operated detectors.	5.1 to 5.4, 5.7.2, 6.2 5.5.2.1 5.7.2.2	 A, G, L, M B
Interlocking devices with non-mechanically actuated detectors: - with magnetically actuated switches; - with electronic proximity switches.	 5.7.3-6.3 5.7.3-6.3	 J K
Systems incorporating keys: - captive-key systems; - trapped-key systems.		 D E
Plug and socket systems	5.7.4	F
Mechanical interlocking between guard and movable parts		H

6. Provisions for the design of interlocking devices (independent of the nature of the energy source)

6.1 Actuation modes of mechanically actuated position detectors

When a single detector is used to generate a stop command, it shall be actuated in the positive mode (see Table 3 and 4.6). Non-positive mode actuation is only allowed in conjunction with a detector with positive mode actuation, notably to avoid common clause failures (see 6.4). The design of the actuator should be as simple as possible, to reduce the possibility of failure.

6.2 Arrangement and fastening of position detectors

6.2.1 Position detectors shall be arranged so that they are sufficiently protected against a change of their position. In order to meet this requirement:

- the fastener of the position detectors shall be reliable and loosening them shall require a tool;
- the use of slots shall be limited to initial adjustment;
- provisions shall be made for positive location after adjustment (e.g. by means of pins or dowels);
- replacement of the detectors shall be possible without any readjusting need.

6.2.2 In addition, the following requirements shall met:

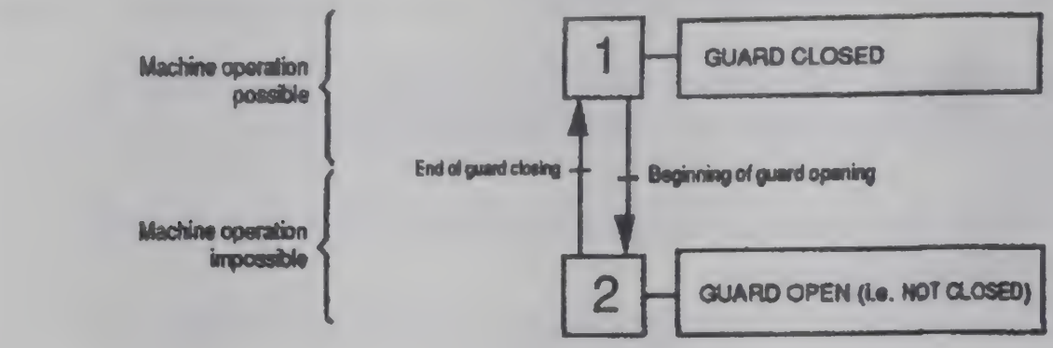
- self-loosening or easy defeat of the detector and of its actuator shall be prevented;
- the support for position detectors shall be sufficiently rigid to maintain correct operation of the position detector;
- the movement produced by mechanical actuation shall remain within the specified operating range of the position detector;
- displacement of the guard before the position detector changes its state shall not be sufficient as to impair the protective effect of the guard;
- the position detectors shall not be used as mechanical stops;
- the position detectors shall be located and, if necessary, protected so that damage from foreseeable external causes is avoided;
- easy access to position detectors for maintenance and checking for correct operation shall be ensured.

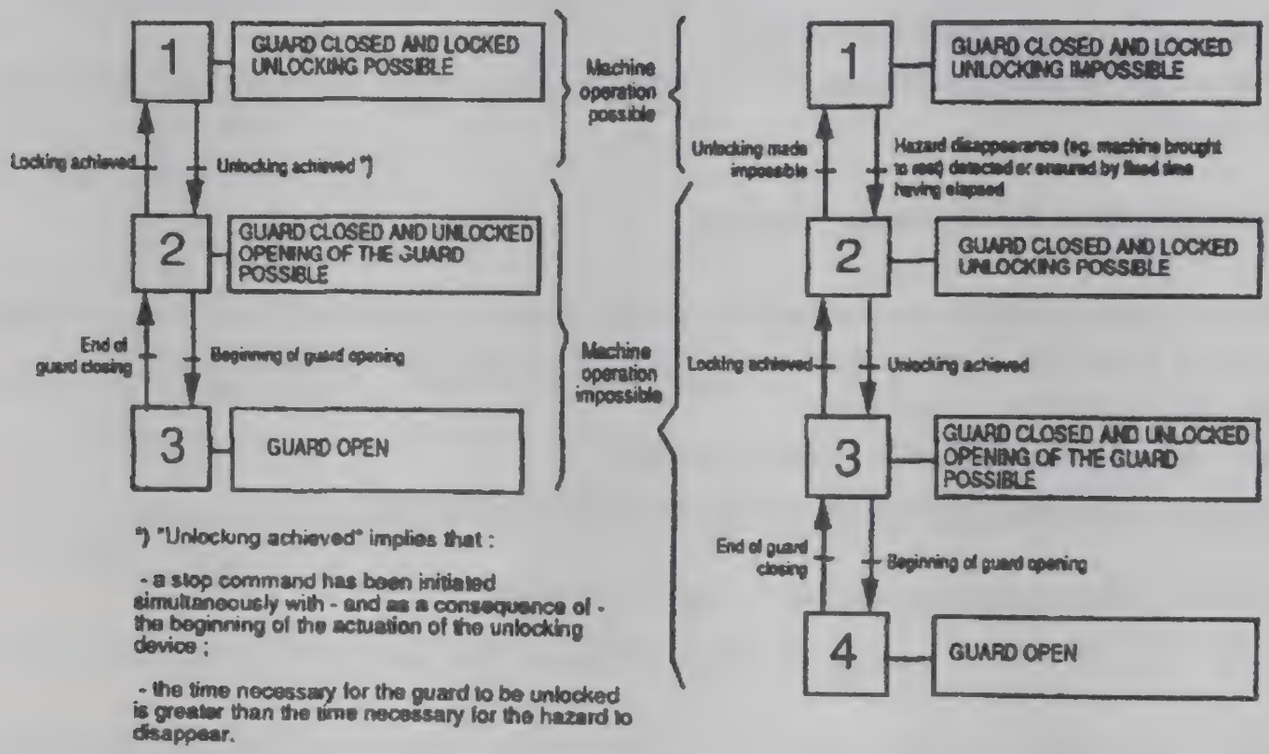
6.3 Arrangement and fastening of cams

Rotary and linear cams for mechanically actuating position detectors shall be designed so that:

- they are positively located, and fixed by fasteners requiring a tool for loosening them;
- their self-loosening is prevented;
- they can only be mounted in a correct position;
- they do not damage the position detector or impair its durability.

NOTE: These provisions exclude friction assemblies.





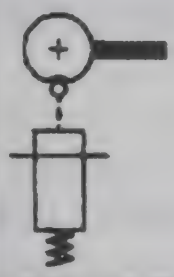
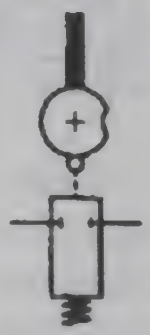
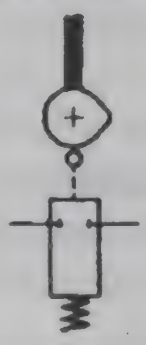
b1) Unconditional unlocking ('three-state interlocking')

b2) Conditional unlocking ('four-state interlocking')

b) Interlocking devices with guard locking

Figure 3. Functional diagrams of the different types of interlocking devices

Table 3. Actuation of position detectors in the positive mode and in the non-positive mode

Mode of actuation	Guard closed	Guard open	Working mode
Positive mode			The detector stem (actuator) is held depressed by a cam as long as the guard is open. When the guard is closed, the detector changes its state as the result of the action of a return spring.
Non-positive mode			The detector stem (actuator) is held depressed by a cam as long as the guard is closed. When the guard is opened, the detector changes its state as the result of the action of a return spring.

6.4 Reducing the possibility of common cause failures

When switching elements have been made redundant, common cause failures shall be avoided, e.g. by use of the measures described in 6.4.1 and/or 6.4.2.

6.4.1 Positive and non-positive mode association of mechanically actuated position detectors (see 6.1)

Typical causes for failure of mechanically actuated position detectors are:

(1) excessive wear of the actuator (e.g. plunge or roller) or of the cam attached to the guard; misalignment between cam and actuator;
(2) jamming of the actuator (plunger) making actuation by the spring impossible.

Detectors actuated in the positive mode, as D1 (see Figure 4), fail to danger in case a), but not in case b). Detectors actuated in the non-positive mode, as D2(see Figure 4), fail to danger in case b), but not in case a). So, in case of a failure of D1 or D2, breaking of the circuit is ensured by the other detector.

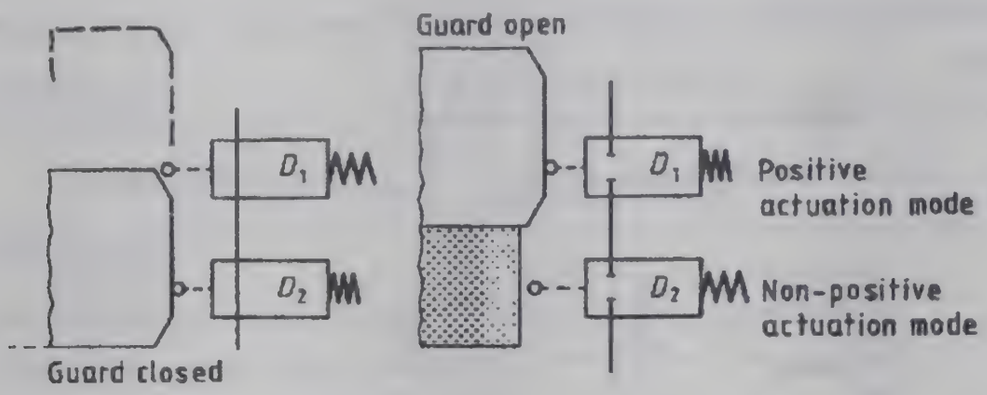


Figure 4. Two mechanically actuated position detectors by using associated positive and non-positive mode actuation

6.4.2 Power medium diversity

In order to minimize the probability of common cause failure, two independent interlocking devices, each of which interrupts the supply from a differentenergy source, may be associated with a guard (see Figure L.3).

6.5 Guard locking device (see 4.4 and 5.2.2)

(1) The part (bolt) intended to lock the guard shall be 'spring applied – power released' (see Figure 2a). For these systems, a manual unlocking device requiring operation by a tool shall be provided.
(2) Other systems (e.g. 2b), 2c)) may be used, if, in a specific application, they provide an equivalent level of safety.
(3) The position of the bolt shall be monitored (e.g. by a detector actuated in the positive mode), so that the machine cannot be started until the bolt is in the fully engaged position (see Annex M).
(4) The bolt shall be able to withstand the forces that are to be expected during normal operation of the guard.
(5) The force that the bolt is able to withstand without damage affecting further use shall be indicated either on the guard locking device itself or in the manufacturer's instructions supplied with the device.

NOTE: Guard locking devices can be used, e.g. to prevent an enclosure around an automatic unit being opened before the machine/process has reached a definite state, thus preventing loss of information or material damage.

6.6 Delay devices

When a delay device (timer) is used, a failure in this device shall not decrease the delay.

6.7 Design to minimize defeat possibilities

6.7.1 General

(1) Interlocking devices shall be designed and instructions for their installation and maintenance shall be given so that they cannot be defeated in a simple manner.

NOTE: 'Defeat in a simple manner' means 'intended operation achieved manually or with a readily available object (e.g. coins, screws, keys, tools, sheet-metal pieces)'.

(2) Provisions by which defeat may be made more difficult include:
- provisions expressed in 6.2.2;
- the use of interlocking devices or systems which are coded, e.g. mechanically, electrically, magnetically, or optically;
- physical obstruction or shielding preventing access to the interlocking device while the guard is open (see examples in Figure 5, 6 and in Annex F, variant b).

Where interlocking systems rely on special actuators or keys (coded or not), advice should be given in the instruction handbook concerning risks associated with the availability of spare actuators or keys and master keys.

6.7.2 Design to minimize defeat of mechanically actuated position detectors

6.7.2.1 Cam-operated position detectors

When a single detector is used, it shall be actuated in the positive mode (see 6.1).

NOTE: A higher level of protection against defeat can be achieved, e.g. by enclosing the cam and detector in the same housing.

6.7.2.2 Tongue-operated switch

As the dependability of the switch relies heavily upon the design of the tongue and mechanism, the switch shall incorporate a system or systems to make it difficult to defeat by simple tools such as pliers, screwdrivers, wire, etc.

A higher level of protection against defeat can be achieved by e.g.:
- physical obstruction or shielding preventing introduction of square actuations (see Figure 5);
- permanent assembly (e.g. by welding, riveting, or one-way screw) of the tongue with the

guard to make dismantling more difficult.

6.7.3 Design to minimize defeat of proximity switches and magnetic switches

(1) Proximity switches and magnetic switches, which rely solely on the presence or absence of detectable material or of a magnet for their actuation, can easily be defeated. Therefore, their method of mounting shall give protection against defeat (see Figure 6).

NOTE: See also 7.3.1 and the standard entitled 'Proximity devices with fault prevention measures or defined behavior under fault conditions' (see Annex P).

(2) Where there is a risk of a substitute actuator being used to defeat the system, an obstruction should be incorporated into the mechanical arrangement to prevent the substitute actuator being used to actuate the switch (see Figure 6).

6.7.4 Design to minimize defeat of plug and socket interlocking devices

Protection against defeat can be achieved by:

- locating the socket so that access to it is prevented when the guard is open (see Annex F, variant b);
- using a multi-pin plug and socket system the wiring of which, being hidden, makes it difficult to restore the continuity of the circuit (see example in Annex F, variant a);
- using a plug and a socket system specifically designed for every particular application, or the spare parts of which are not readily available.

6.8 Environmental considerations

The selection of an interlocking device and/or its components shall take into account the environment (e.g. temperature) in which they are intended to be used.

7. Additional technological requirements for electrical interlocking devices

7.1 Other requirements for safety

- The degree of protection shall be so proper as to protect the electric interlocking devices against ingress of solids and fluids (see Annex 2 of KOSHA CODE E-11-98).
- Position sensors shall be of the direct opening operation type.

NOTE: For the purpose of this standard, a position sensor, a position detector, and a position switch are considered to be the same type of device.

7.2 Interlocking devices incorporating mechanically actuated position switches

7.2.1 Interlocking devices incorporating one single mechanically actuated position switch
7.2.1.1 The position switch shall be actuated in the positive mode (see 4.5 of EN 292-2 and also 4.6 and 6.1 of this standard).

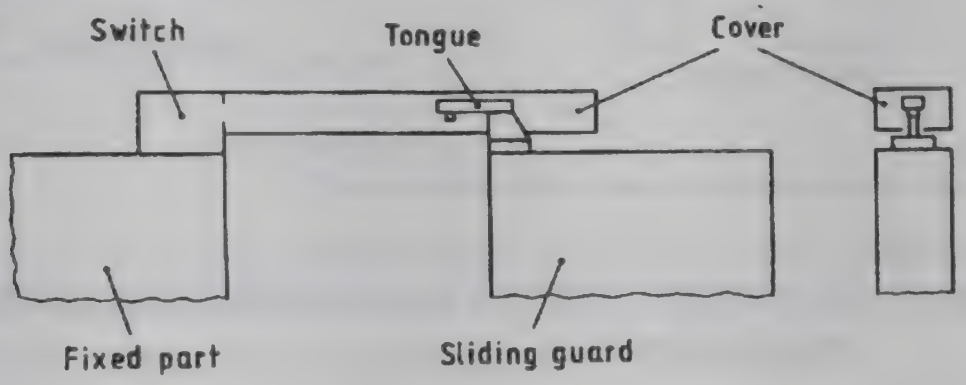


Figure 5. Example of protection against defeating a tongue-operated switch

7.2.1.2 The break contact of the position switch shall be of the positive opening operation type (see also 4.7 of this standard and Annex A and B).

7.2.2 Interlocking devices incorporating two mechanically actuated position switches

The position detectors should operate in opposite modes (see Figure 4):

- one with a normally closed contact (break contact), actuated by the guard in the positive mode;
- the other with a normally open contact (make contact), actuated by the guard in the non-positive mode (see Annex G).

NOTE: This is a common practice. It does not exclude, when justified, the use of two switches actuated in the positive mode.

7.3 Interlocking devices incorporating non-mechanically actuated position switches (proximity switches and magnetic switches)

An interlocking device incorporating non-mechanically actuated position switches can be used to overcome problems arising from the use of mechanically operated switches when a guard can be removed completely from a machine and or when the environmental conditions require a sealed switch. See also Figure 6 and Annex J and K.

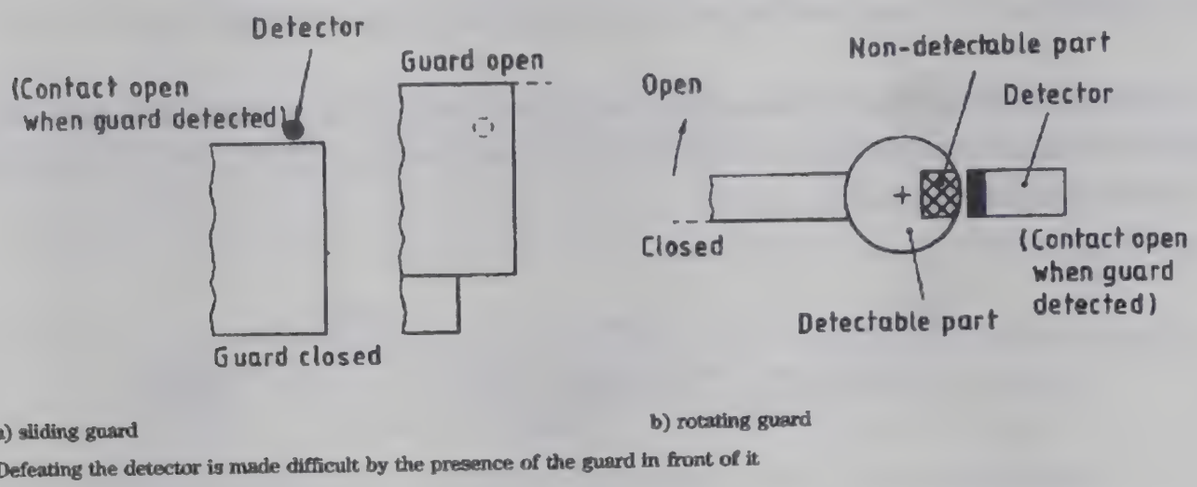


Figure 6. Examples of protection against defeat of a proximity switch or magnetic switch

7.3.1 Equivalence in safety

When non-mechanically actuated position switches are used, the safety achieved shall not be less that obtainable with mechanically actuated position switches.

Equivalent safety may be achieved for instance by:

- minimizing the possibility of defeat (see 6.7.3);
- using the design techniques, especially duplication (or redundancy) or automatic monitoring, as well as diversity of design and/or technology to avoid common cause failure.

7.3.2 Immunity from disturbance

Proximity switches and magnetic switches for interlocking applications shall be selected and used so that foreseeable external fields do not impair their function.

7.3.3 Mutual influencing

Proximity switches shall be mounted so that malfunction caused by mutual influence is prevented.

7.3.4 Electrical operating conditions

When proximity switches and magnetic switches are used in interlocking devices, necessary precautions shall be taken to prevent malfunction caused by voltage fluctuations, transient overvoltage, etc.

7.3.5 Specific provisions for magnetic switches

(1) Magnetic switches used without additional measures, such as overcurrent protection and/or redundancy and automatic monitoring, are generally not suitable for interlocking applications principally because they can fail to danger.
(2) Malfunction by vibration shall be prevented (see 5.7.3 and Annex J).

8. Selection of an interlocking device

8.1 General

The aim of this clause is to advise machine designers on how to select an interlocking device suitable for a specific application. In selecting an interlocking device for a machine, it is necessary to consider all phases of the interlocking device life cycle.

The most important selection criteria are:

- the conditions of use and the intended use (see 3.12 of EN 292-1) of the machine (see 8.2);
- the hazards present at the machine (see 8.3); - the severity of possible injury (see 8.3);
- the possibility of failure of the interlocking device (see 8.3);
- stopping time and access time considerations (see 8.4);
- the frequency of access (see 8.5 and 8.3);
- the duration of person exposure to the hazard (see 8.3);
- performance considerations (see 8.6).

8.2 Conditions of use and intended use

The type of interlocking devices selected shall be suitable for the conditions of use (e.g. environment) and for the intended use of the machine.

8.3 Risk assessment

In order to select the most appropriate interlocking device for a given machine in definite conditions of use, the designer has to carry out the risk assessment process, taking into account different types of interlocking devices until adequate safety is achieved.

The risk to be assessed is the risk that would occur if the safety function of the interlocking device was not performed.

8.4 Stopping time and access time

An interlocking device with guard locking shall be used when the stopping time (see

definition in 4.8) is greater than the time (called access time: see definition in 4.9) taken by a person to reach the danger zone.

8.5 Frequency of access (frequency of opening the guard for access to the danger zone)

8.5.1 For applications requiring frequent access, the interlocking device shall be chosen to provide the least possible hindrance to the operation of the guard (taking into account the requirements of 8.2, 8.3 and 8.4).

NOTE: A clear distinction should be made between the following:

- the concept of frequent access required by the normal operation of the machine, e.g. once per cycle to feed raw products to the machine and remove finished products;
- the concept of occasional access, e.g. to carry out adjustment or maintenance interventions, or for random corrective actions in danger zones.

Each of these concepts is associated with an order of magnitude differing greatly as to the frequency of human intervention in the danger zone (for example one hundred times per hour in the case of one access per cycle, and several times per day in the case of occasional access for adjustment or maintenance during an automatic production process).

8.5.2 For applications using interlocking devices with automatic monitoring, a functional test can be carried out every time the device changesits state. If, in such a case, there is only infrequent access, the interlocking device should be used with additional measures such as conditional guard unlocking (see Figure 3b2), as between consecutive functional tests the probability of occurrence of an undetected fault is increased.

8.6 Performance considerations

Control interlocking devices are safety-related parts of the control system of a machine. It is therefore essential that a control interlocking device is compatible with the machine control system, to ensure that the required safety performance is achieved.

If power interlocking is used, the components shall have the suitable breaking capacity, taking into account all foreseeable situations (e.g. overload).

ANNEX A

Guard-operated interlocking device with one single cam-operated position detector

1. Principles

One single detector, actuated in the positive mode, monitors the position of the guard (see 6.1 'Actuation modes of mechanically actuated position detectors)

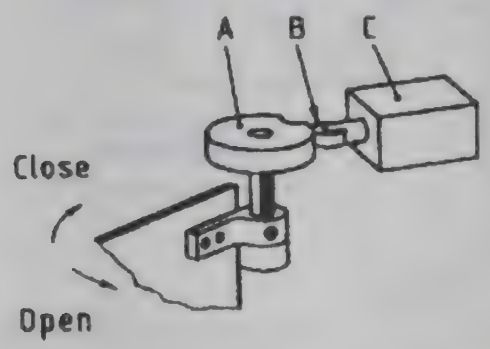


Figure A.1 With a rotating guard

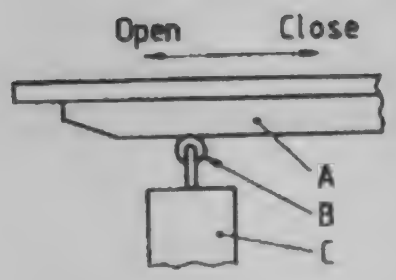


Figure A.2 With a sliding guard

2. Advantages

- Positive mechanical action of the cam (A) of the actuator (B) of the position detector (C)- Impossible to defeat by manually operating the actuator without moving cam or detector.

3. Disadvantage

Fails to danger in case of: - wear, breakage, etc. causing malfunction of the actuator; - maladjustment between the detector and the cam.

4. Remarks

As the absence of the guard is not detected, it is essential that the guard cannot be dismantled without tools. See also: - 6.2 'Arrangement and fastening of position detectors' - 6.3 'Arrangement and fastening of cams'.

Example Electrical interlocking device incorporating one single cam-operated switch (see 6.2.1)

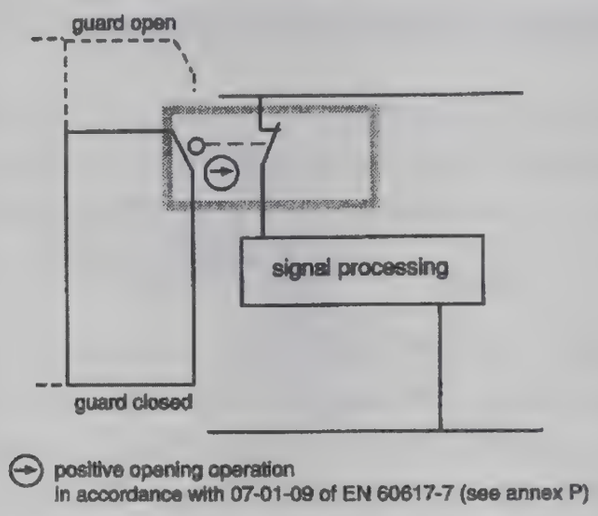


Figure A.3

(1) Advantages
- Positive mechanical action of the guard on the actuator of the switch.
- Positive opening operation of the break contact of the switch (see 4.7).

(2) Disadvantages
Fails to danger in case of:
- failure of the mechanical link between guard and switch;
- electrical by-passing of the switch

ANNEX B

Guard-operated interlocking device with tongue-operated switch

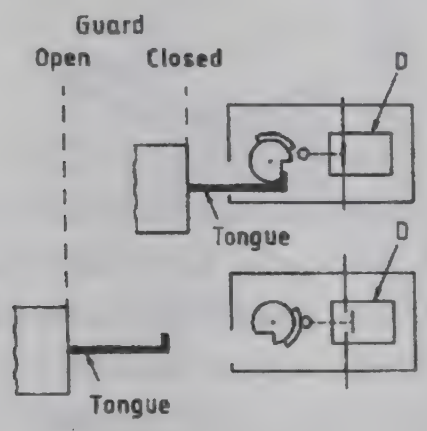


Figure B.1

1. Principle

The device comprises: - a circuit-breaking element (D); - a mechanism which, when operated, causes the circuit-breaking element to be opened and closed (for electrical devices: positive opening operation; see 4.7)

A specially shaped part (tongue) is fixed on the guard (e.g. riveted) so that this tongue cannot be easily removed. The circuit-breaking element only ensures the continuity of the circuit when the tongue is inserted into the detector. When the tongue is withdrawn (when opening the guard), it operates in the positive mode the mechanism that opens the circuit-breaking element.

2. Advantages

Only a small displacement of the guard is needed for the detector to change its state. Especially suitable for use: - on the opening edge of a guard (door); - with guards which can be removed without the use of tools; - with guards having neither a hinge nor a guide connecting them to the machine.

3. Disadvantages

Can be defeated by using a tongue which is not attached to the guard.

4. Remark

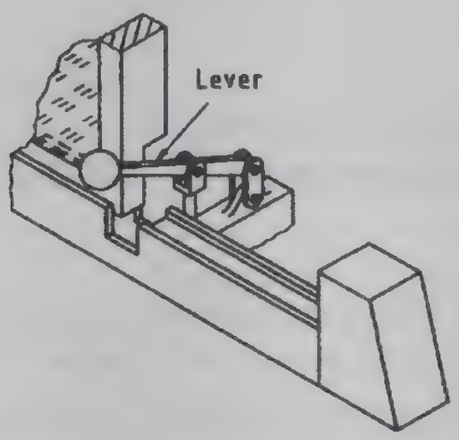
For measures against defeating, see 6.7.2.2.

ANNEX C

Direct (mechanical) interlocking between guard and start / stop manual control

1. Principle

As long as the 'start/stop'manual control (in this case a lever) is in the raised position, it prevents the guard being opened. Lowering the level causes the device it actuates to positively interrupt circuit continuity (thus directly interrupting power that actuator(s) if the device is part of the power circuit, or generating a stop command if it is a control device). When the lever is in the lower position, it is possible to open the guard. As long as the guard is open, it prevents the lever being lifted.



'Start/sop' lever prevents the guard being opened

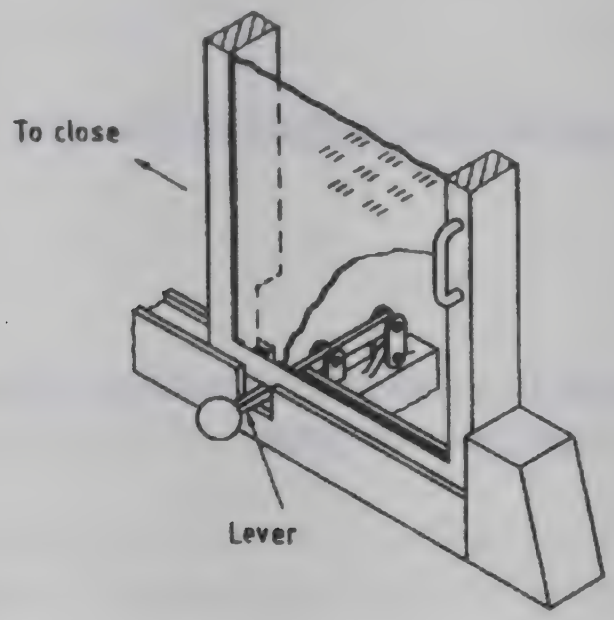
Figure C.1 Guard closed

2. Advantages

Reliability through simplicity, especially when used as a power interlocking device (see 5.1.2)

3. Remark

The lever (or its equivalent) is designed to withstand the expected forces and cannot be easily dismantled. A mechanical stop prevents overtravel of the guard.



Guard prevents lifting 'start / stop / lever, thus preventing restoration of circuit continuity

Figure C.2 Guard open

ANNEX D

Captive-key interlocking device

1. Structure

A combination of a switch and a lock is secured to a fixed part of the machine. The operating key is held captive on the moving part of the guard.

2. Principle

The operating principle of captive-key interlocking devices is described by the sequence of operations for guard opening:

(1) turn handle to switch off (stop command is given);
(2) further turn to unlock guard;
(3) open guard (key disengages from lock).

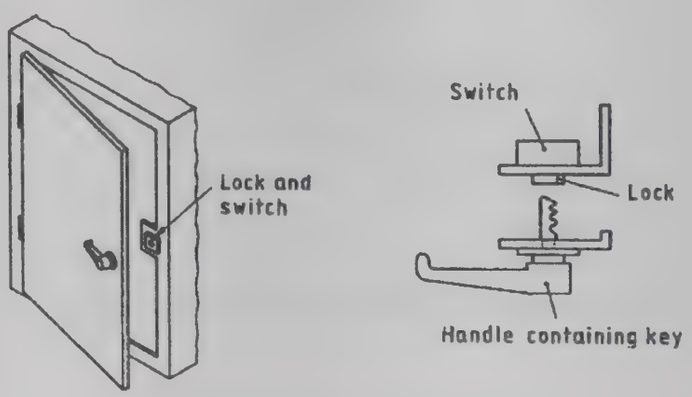


Figure D.1

3. Advantages

Ensures that the circuit-breaking element will be opened before the guard can be opened. Especially suitable when the guard is hinged or can be removed completely.

4. Remarks

Can be combined with a time-delay unit. Thus, it becomes an interlocking device with guard locking with conditional unlocking (see Figure 3b2).

ANNEX E

Trapped-key interlocking device

1. Principle

A trapped-key interlocking device is an interlocking device relying upon the transfer of keys between a control element and a lock fixed on the guard (guard lock).

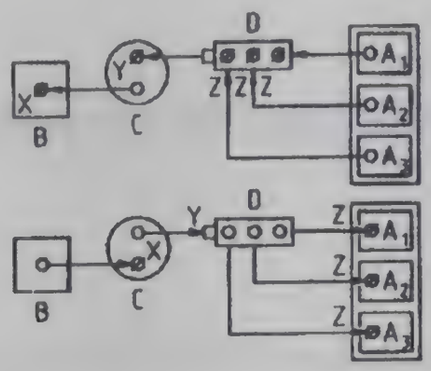
In a trapped-key interlocking device, the guard lock and the switching element, which also incorporates a lock, are separate as opposed to being combined into a single unit as in the captive key interlocking device.

The essential feature of the system is that the removable key is trapped either in the guard lock, or in the switch lock. The lock on the guard is arranged so that the key can be released only when the guard has been closed and locked. This allows transfer of the key from the guard to the switch lock. Closing the switch traps the key, so that it cannot be removed while the switch is in the ON position.

If there is more than one source of power, and therefore more than one circuit-breaking element to be actuated, then a key-exchange box (D) is necessary, to which all keys have to be transferred and locked in before the access key, which is of a different configuration, can be released for transfer to the guard lock. Where there is more than one guard, the exchange box will accommodate an equivalent number of access keys.

Where, for the purpose of the process or of safety, a number of operations have to be carried out in a definite sequence, then the transferable key is locked in and exchanged for a different one at each stage. The exchange box can be integral with the lock.

Figure E.1 Basic diagram



A (A_1,A_2,A_3) Lock(s) on guard(s)
B Lock on circuit-breaking element
X,Y,Z keys Lock without a key trapped in it O
Lock with a key trapped in it Ø

Figure E.2 Variant with time delay device (C) and key exchange box1) (D)

2. Advantages

- No reduction of integrity due to the distance between guard and control system.
- No need for electrical wiring to each guard.
- Suitable when the guard is placed in hostile environment.
- Can be used when the guard can be removed completely.
- Particularly suitable when several different types of power source are present on the machine and for power interlocking.
- Personal keys can be released for access to guarded areas where persons could become enclosed.

3. Disadvantages

- Not suitable for applications requiring very fast access times.
- Duplicate keys can become available for defeating (see 6.7.1).

4. Remark

Delay between opening of the circuit-breaking element and unlocking of the guard is ensured merely by key-transfer time (increased, if necessary, by a time-delay device).

A key-exchange box is required when either a guard is interlocked with two or more machine controls, or two or more guards are interlocked with one machine control.

ANNEX F

Plug and socket interlocking device (plug / socket combination)

1. Principle

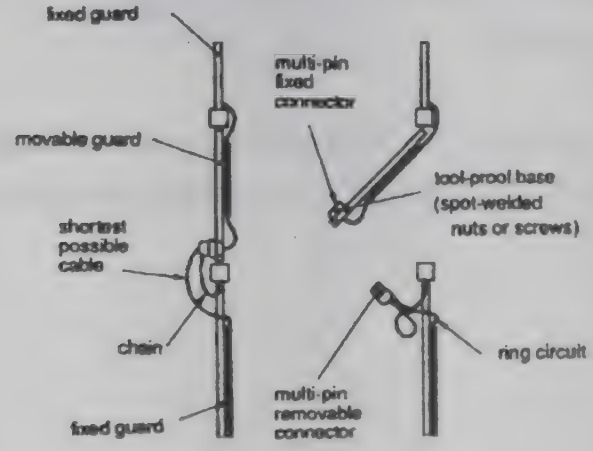
Circuit breaking by unplugging A plug and a socket (or base) are used as an interlocking device, one part mounted on the machine, the other part on the guard.

2. Advantage

Reliability through simplicity

3. Disadvantages

Generally not suitable for applications requiring very frequent access.

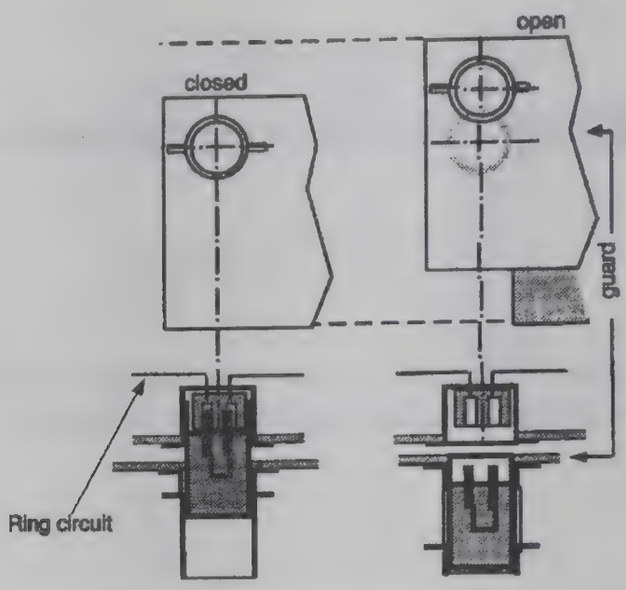


Variant a: hinged (rotating) guard

Figure F.1

Pins and sockets are accessible when the plug is removed from the socket. It is thus easy to complete the circuit using electric lead(s) when the guard is open.

A possible measure to prevent this method of defeat is by the use of a multi-pin connector. Since the wiring arrangement is complex, it is more difficult to restore the continuity of the circuit when the guard is open.



Variant b: laterally sliding guard

Figure F.2

Both pins of the plug are linked to ensure that, when the guard is closed and the plug inserted into the socket, the circuit is complete.

As the plug remains fixed to the guard and the guard covers the socket when open, it is not possible to restore the integrity of the circuit by inserting a bridging link into the socket.

ANNEX G

Guard-operated interlocking device incorporating two cam-operated position detectors

1. Principle

One detector is actuated in the positive mode. The other one is actuated in the non-positive mode (see 6.1).

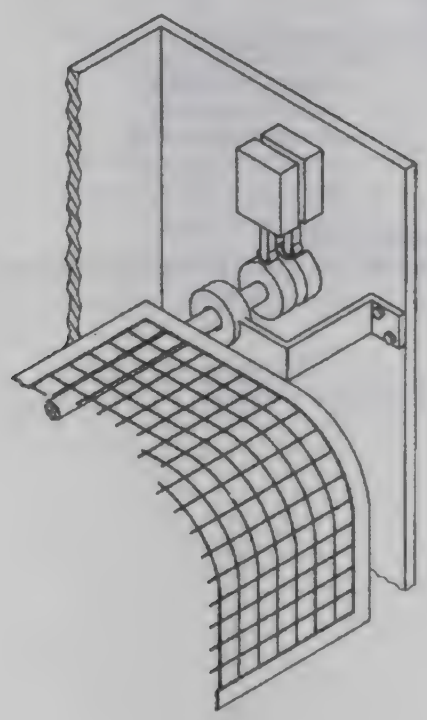


Figure G.1

2. Advantages

Duplication of detectors avoids failure to danger in case of a single fault. Diversification of redundant components reduces the risk of common cause failure. The non-positively actuated detector detects the absence of the guard.

3. Remark

Without monitoring, one faulty detector remains undetected, until a fault in the second detector results in failure to danger.

Example

Electrical interlocking device with two cam-operated switches (see 7.2.2)

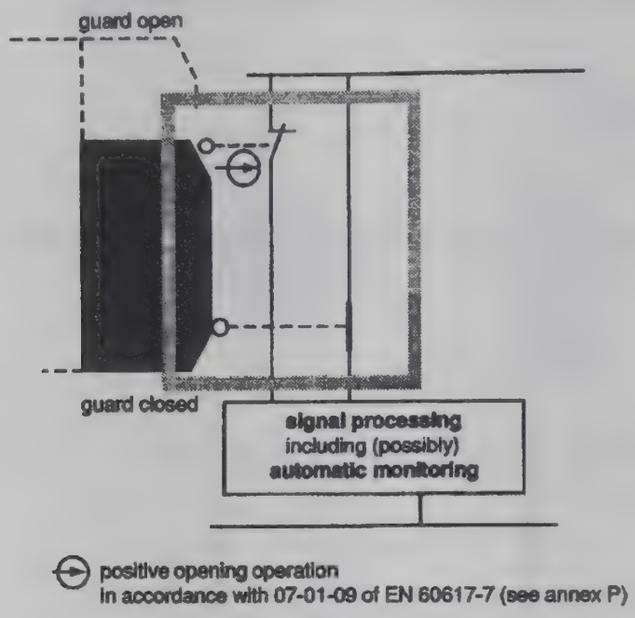


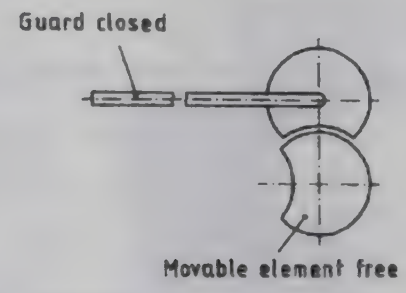
Figure G.2

ANNEX H

Mechanical interlocking between a guard and a movable element

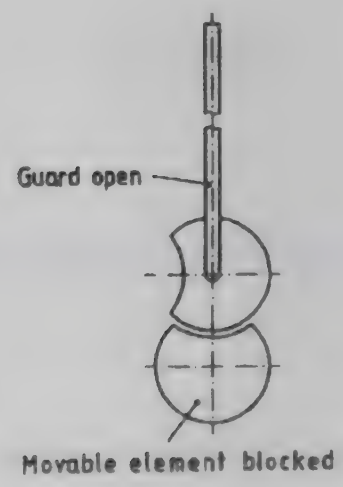
1. Principle

Direct mechanical interlocking between a guard and a hazardous movable element. The function ensured is that of an interlocking guard with guard locking.



As long as the movable element is not at rest, the guard is locked in the closed position.

Figure H.1 Guard closed



As soon as the guard is no longer in the closed position, the movable element is blocked.

Figure H.2 Guard open

2. Remark

The application is limited to very simple mechanisms. Manual positioning of the movable part may by required to make it possible to open the guard.

ANNEX J

Electrical interlocking device incorporating magnetically actuated (magnetic) switches

1. Principle

A coded magnet, fitted to the guard, actuates a normally open and a normally closed Reed switch.

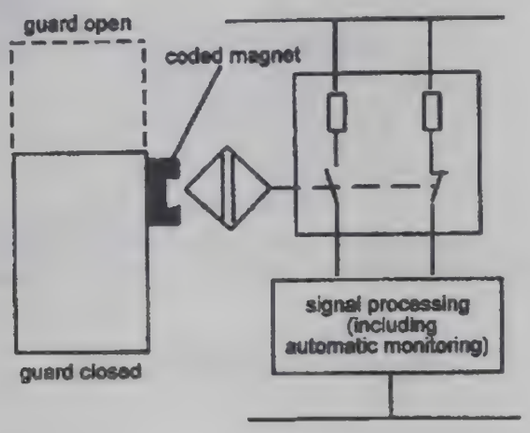


Figure J.1

2. Advantages

Compact; no external moving parts. High resistance to dust, liquids. Easily kept clean.

3. Disadvantages

Sensitive to electromagnetic interference. No positive opening of contacts. Possible contact welding in case of overcurrent.

4. Remarks

The disadvantages mentioned above make it necessary for the magnetic switches to be automatically checked at each switching cycle, and for overcurrent protection to be provided (see 7.3.5).

The device is designed so as to require a coded magnet in order to be actuated. This prevents it being defeated in a simple manner. ANNEX K

Electrical Interlocking Device Incorporating Two Proximity Switches

1. Principle

D1and D2 are proximity detectors, able to detect metal parts (in this case, the guard).

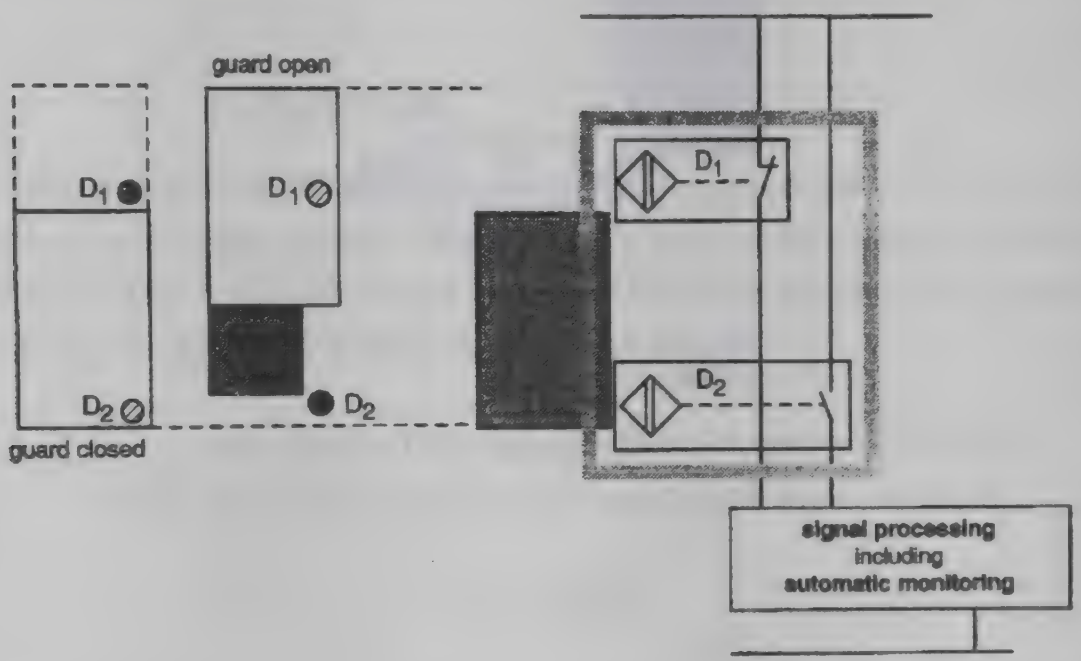


Figure K.1

2. Advantages

No moving parts. High resistance to dust, liquids. Easily kept clean. Compact.

3. Disadvantages

Sensitive to electrical interference. No positive opening operation of contacts. Possibility of contact welding causing failure to danger if no overcurrent protection is ensured.

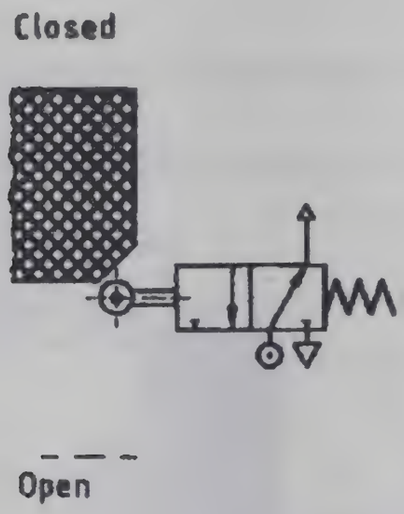
4. Remarks

As long as it is open, the guard conceals D1, thus preventing defeat of this detector by simple means.

It can be of advantage to have, in the interlocking device, two switches with substantially different technological properties, so that it would be highly improbable that the same spurious phenomenon can affect them simultaneously (this is known as diversity or heterogeneous redundancy and is intended to prevent 'common cause failure').

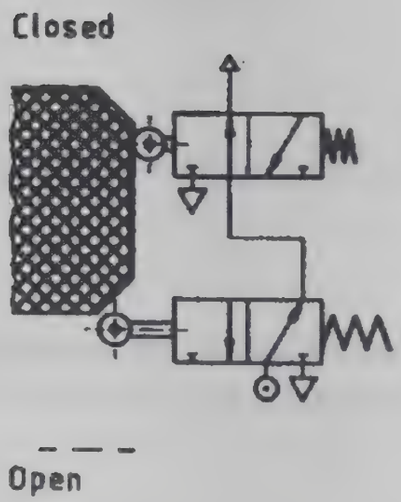
ANNEX L

Pneumatic/hydraulic interlocking devices



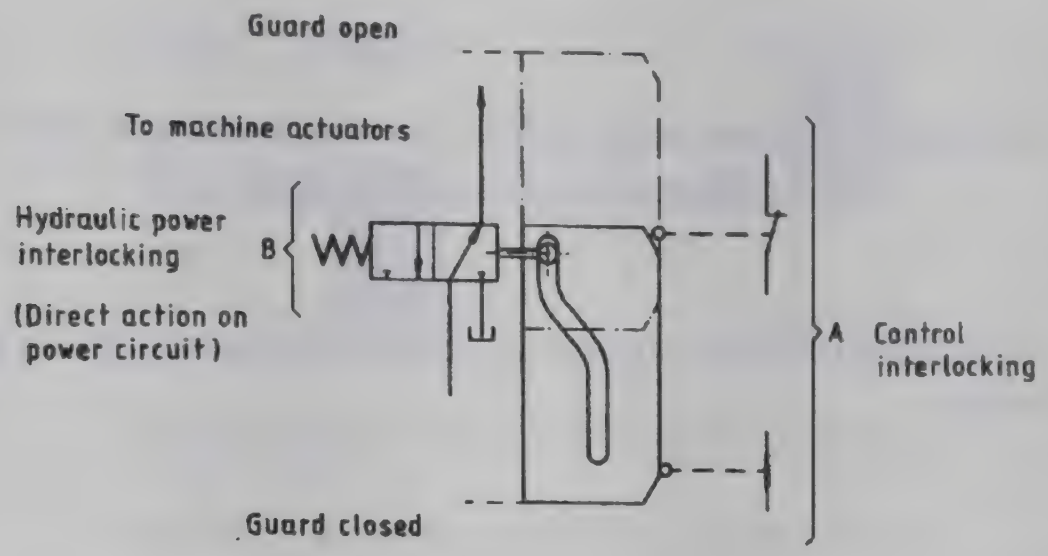
One single circuit-breaking element (valve) with positive-mode actuation of the single valve by the guard

Figure L.1



Two circuit-breaking elements (valves)

Figure L.2



Two independent interlocking devices (A and B) are provided: A acts on the electrical control circuit (with automatic monitoring); B acts on the hydraulic circuit (power interlocking (see 5.1.2) when direct interruption of the power circuit is possible) Hybrid (electrical and hydraulic) interlocking device.

Figure L.3

Remark

A hybrid interlocking device is particularly interesting in very severe environmental conditions which may induce 'common mode failure' (i.e. simultaneous failures having the same cause) of components with the same technology, e.g. melting of the insulating layer of conductors on a machine working under hot conditions, or simultaneous failure of two proximity detectors under the effectof electric or electromagnetic interference.

ANNEX M

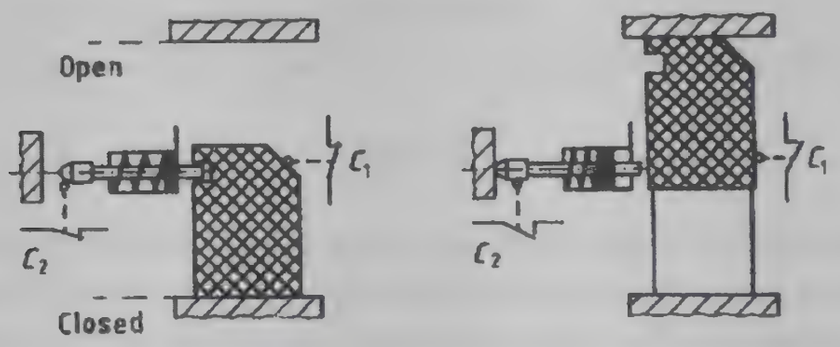
Interlocking device with spring applied/power released guard locking device

1. Variant A: Interlocking function ensured by detecting separately guard position and lock position

Principle

C_1 detects the position of the guard, C_2 detects the position of the lock.

Release of the lock when the hazard has disappeared can be controlled either by a timing device (timer) or by a stop-detection device.



C1 and C1 may be detectors of any technological type (see 5.3)

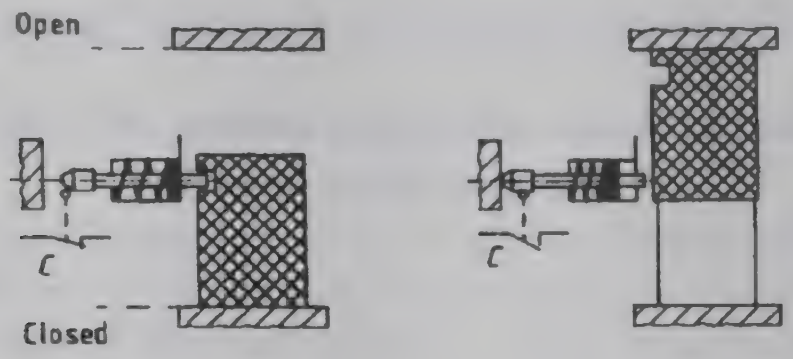
Figure M.1 Separate detection of guard position

2. Variant B: Interlocking function ensured by detecting lock positiononly

Principle

In detecting the lock position, one single detector (C) also monitors the guard position, provided that the condition 'C cannot close if the guard is not closed' is rigorously and reliably performed due to good design and construction of the 'guard-lock contact (C)' assembly.

Release of the lock when the hazard has disappeared can be controlled either by a timing device (timer) or by a stop detection device.



C may be a detector of any technological type (see 5.3)

Figure M.2 Integrated detection of guard position

3. Remarks (for both variants)

Whatever device (electromagnet, cylinder, etc.) is used to actuate the lock which keeps the guard closed, it is essential that fail-safe conditions be established: i.e. that, if power supply is cut, the lock remains in the position in which it makes the guard immobile.

ANNEX N

Interlocking device with guard locking, with manually operated delay device

1. Principle

The threaded pin is turned by hand (unconditional unlocking, according to Figure 3b1). The time elapsing between the switch opening and guard release is determined so that it is longer than the time taken to stop the hazardous functions.

When opened, the guard prevents the pin being screwed in again, thus closing the switch contacts.

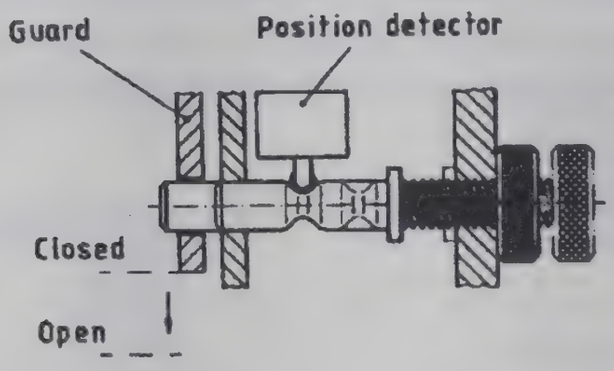


Figure N.1

2. Advantage

Reliability through simplicity

Design and Testing of Visual Danger Signals

1. Purpose

This standard, based on the European Standard EN 842, describes the criteria for the perception of visual danger signals for machinery and equipment designers, according to Article 34-2 of the Industrial Safety and Health Act, Article 59-3 of the Enforcement Decree of the Industrial Safety and Health Act, and Article 4 of the Safety Certification Regulation for Machinery and Equipment (Notification No. 2003-15 of the Ministry of Labor).

2. Scope

2.1 This standard specifies the safety and ergonomic requirement sand the corresponding physical measurements and subjective visual check. It also provides guidance for the design of the signals to be clearly perceived and differentiated as described in 5.3 of EN 292-2.

2.2 Exceptions

The standard does not apply to danger indicators:

(1) presented in either written or pictorial form;
(2) transmitted by data display units.

3. Definitions

3.1 Visual danger signal: Visual signal indicating imminent onset, or actual occurrence of a dangerous situation, involving risk of personal injury or equipment disaster, and requiring some human response to eliminate or control the danger or requiring other immediate action. Visual danger signals are divided into two types: visual warning signal and visual emergency signal.

3.2 Visual warning signal: Visual signal indicating the imminent onset of a dangerous situation requiring appropriate measures for the elimination or control of the danger.

3.3 Visual emergency signal: visual signal indicating the beginning or the actual occurrence of a dangerous situation requiring immediate action.

3.4 Signal reception area: Area in which the signal is intended to be perceived and reacted upon.

3.5 Field of vision (visual field): Physical space visible to an eye in a given position.

3.6 danger signal light: :Light source intended to convey information about the existence of a dangerous situation by means of one or several characteristics, such as luminance, color, shape, location, and temporal pattern.

4. Safety and ergonomic requirements

4.1 General

(1) The characteristics of the visual danger signal shall ensure that any person in the signal reception area can detect, discriminate, and react to the signal as intended. Visual danger signals shall be: - clearly seen under all possible lighting conditions; - clearly discriminated from general lighting and other visual signals; - allocated a specific meaning within the signal reception area.
(2) Visual danger signal shall take precedence over all other visual signals. Visual emergency signals shall take precedence over all visual warning signals.
(3) Care shall be taken to review the effectiveness of the visual danger signals at regular intervals and whether a new signal (whether a danger signal or not) is introduced in the signal reception area.

NOTE 1: A visual danger signal should, if not contradicted by special reasons, be associated with an auditory danger signal. When the danger signal is an emergency signal, auditory and visual signals should be presented together (EN 981).

NOTE 2: It could be advantageous for visual danger signals to have a relatively low intensity test mode to indicate they are functional but not in a warning mode.

NOTE 3: The criteria for detectibility characters are the luminance of the surface, the luminance of the background and their ratio.

NOTE 4: The luminance ratio (contrast) is not affected by viewing distance, so a specified luminance ratio can be considered adequate for a wide range of viewing conditions.

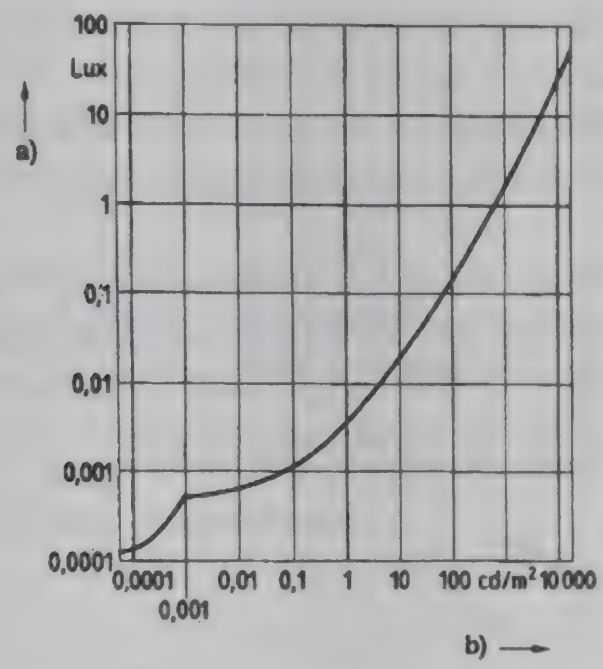
4.2 Detectibility

4.2.1 Luminous area sources

(1) The luminance of a visual warning signal shall be at least five times the luminance of the background.
(2) The luminance of a visual emergency signal shall be at least twice that of a warning signal, i.e. at least ten times the luminance of the background.

4.2.1.2 Luminous point sources

For luminous point sources, the criterion for detectibility is the illuminance produced by the luminous flux on the pupil of the observer's eye compared to the luminance of the background. The relationship between the papillary illuminance required for detectibility and the background luminance is given in Figure 1.



a) Required papillary illuminance in Lux
b) Background luminance in cd/m2

Figure 1. Relationship between the required papillary illuminance and the background luminance

4.2.2 Flashing lights

By having a signal flash, i.e. continuously switching ON and OFF, the detectibility (sttention-attracting qualities) of the signal is usually increased, often accompanied by transmission of a feeling of urgency.

NOTE1: It is recommended that the flash frequency should be between 2 Hz and 3 Hz with approximately equal ON- and Off-intervals.

NOTE 2: Synchronism between light and sound is not generally required, but can improve perception.

NOTE 3: Stroboscopic effects from, e.g. rotating machinery, can reduce the detectibility of flashing light signals.

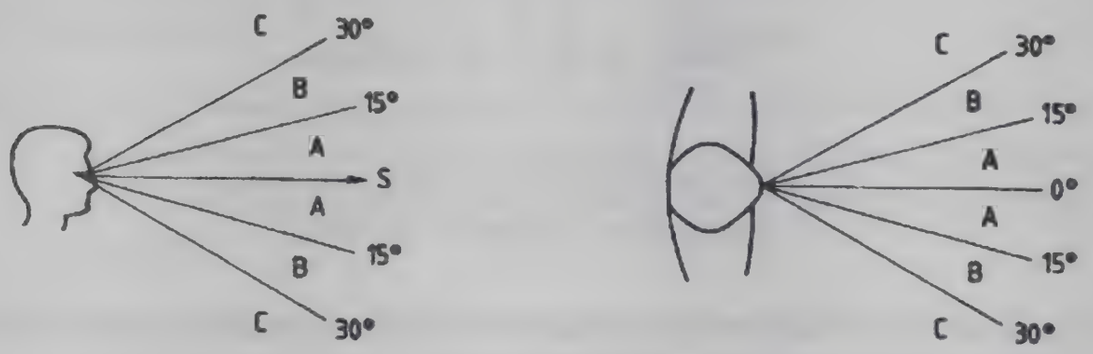
4.2.3 Location within the field of vision

(1) Visual danger signals should be located where appropriate in the direct vicinity of the potential danger in order to allow its immediate detection by all persons within the signal reception area, or about to enter in this area. Additional visual danger signals located outside the direct vicinity, such as in a control room or a control panel, are not excluded.

(2) The signal reception area of a visual danger signal shall be explicitly stated in the design for every installation, indicating whether the signal reception area is, e.g. just a single operator's console or parts of a factory or a whole part.

(3) For directly displayed danger signals, the signal lights shall be located within the field of vision inside the workplace being considered (signal reception area) (see Figure 2 and 3 and prEN 894-2).

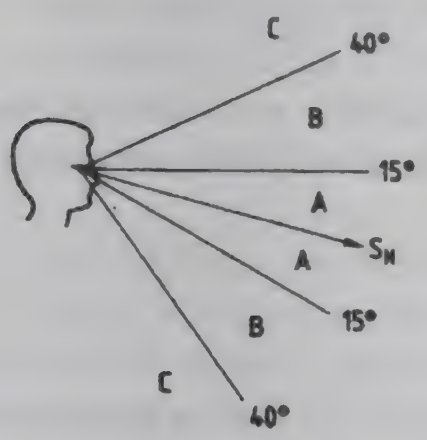
(4) When the direction of the eye changes as a result of the work activity, or when the fields of vision of several people are non-overlapping, additional signal lights shall be installed. The signaling devices shall be positioned so that at least one danger signal is visible from any point within the signal reception area.



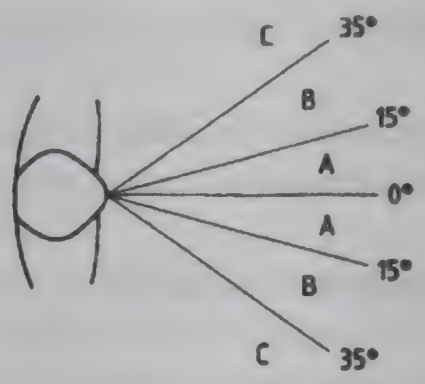
a) Vertical field of vision (b) Horizontal field of vision

Zone A: Recommended
Zone B: Acceptable
Zone C: Not suitable
Line S: Imposed line of sight

Figure 2. Field of vision when line of sight direction is imposed by external task requirements.



a) Vertical field of vision



(b) Horizontal field of vision

Zone A: Recommended
Zone B: Acceptable
Zone C: Not suitable
Line SN: Normal of sight, 15° to 30° below the horizontal

Figure 3. Field of vision when line of sight direction is not imposed by external task requirements.

4.3 Discriminability

4.3.1 General

(1) When a visual danger signal has been detected it is of vital importance that the correct measures are taken; therefore the signal information needs to be transmitted unambiguously.

(2) Discrimination between visual danger signals shall be accomplished using at least two means of the following characteristics:
- color of signal light - location; - relative position of lights - temporal pattern - glare.

4.3.2 Color of signal light

(1) A visual warning signal shall be yellow or yellow-orange. A visual emergency signal shall be red.

(2) If visual warning and visual emergency signals are used both in a working area, and if despite the difference in color the signals cannot be clearly discriminated, the emergency signal shall have at least twice the intensity of that of the warning signal.

NOTE 1: For the choice of colors in a system of auditory and visual danger and information signals, see EN 981.

NOTE 2: Colors of signal lights and their meaning shall be in accordance with EN 60073, EN 61310-1, and ISO 3864.

4.3.3 Location

Whenever possible the visual danger signal should be placed so as to facilitate immediate and correct understanding of the nature of the danger and of the immediate measures to be taken.

4.3.4 Relative position of lights

If two or more signal lights are used in a signaling device the red signal shall always be positioned above the yellow one. If two red lights are used, they shall be horizontally aligned.

4.3.5 Temporal pattern

Flashing lights shall be used for visual emergency signals. It is preferable to use more than one light in the same signaling device, to allow both a spatial and a temporal pattern of flashing.

4.4 Glare

The detection and discrimination of a visual danger signal are specified in 4.2 and 4.3 shall not be impaired by glare caused by other light sources in the signal reception area, e.g. sunlight.

4.5 Distance

(1) The distance between light source and observer should be kept as small as practical in order to increase the papillary illuminance or reduce the necessary light output.

NOTE: The distance between a light source and the observer's eye determines the amount of light reaching the eye since the illuminance is inversely proportional to the square of this distance.

(2) Auditory danger signals should be used in the cases below:
- the luminous flux of the signal is additionally reduced y the lowered transmissivity of the medium because there is fog, rain, snow, smoke, steam, or dust between the light source and the observer;
- the transmissivity can be so low as to make light signals practically ineffective.

4.6 Duration

After the dangerous condition has been perceived and corrective action has been taken, the signal should be changed to a less urgent level. If the remaining hazard is negligible or controllable the warning light should be switched off.

NOTE: When a visual danger signal is no longer required, an ALL CLEAN signal in accordance with EN 981 should be used.

5. Physical measurements

Measurements of illuminance and/or luminance should be made as confirmations that the visual danger signals meet the requirements and recommendations of this standard.

6. Subjective visual check

(1) Considering the enormous complexity of the visual environment in many places and also considering the widely differing personalities and abilities of the possible observers, a system of visual danger signals should be checked with a representative sample of people. In order to be representative, the group shall include also persons:

- more than 45 years old;
- with visual acuity less than 0.8;
- with color vision detects
- wearing eye protection (goggles).

NOTE: To perform a subjective visual check, small groups of persons (five or less) are observed while the visual danger signal is presented without any previous notice. If the observed people react with spontaneous gestures or comments, the check can be terminated. If some persons do not display any overt reactions, they are asked immediately after the observation period about their visual perceptions during the last several minutes. Depending on the answers received, the outcome of the visual check can be taken as an indication of the effectiveness of the visual danger signal(s).

(2) The subjective visual check should be repeated a number of times at various locations, with various persons and different lighting conditions, until a representative set of observations has been obtained.

(3) The system of visual danger signals is considered adequate if all persons observed exhibited a reaction.

Auditory Danger Signals

1. Purpose

This standard, based on the European Standard EN 457, specifies the criteria for the design of auditory danger signals in the signal reception area especially in cases where there is a high level of ambient noise, according to Article 34-2 of the Industrial Safety and Health Act, Article 59-3 of the Enforcement Decree of the Industrial Safety and Health Act, and Article 4 of the Safety Certification Regulation for Machinery and Equipment (Notification No. 2003-15 of the Ministry of Labor).

2. Scope

2.1 This standard applies to the auditory danger signals to be clearly perceived and differentiated as required for S2-G-15-1999.

2.2 Exceptions

The standard does not apply to:

(1) verbal danger warnings (e.g. shouts, loudspeaker announcements);
(2) sound danger signals covered by special regulations for a public disaster and public transport.

3. Definitions

3.1 Auditory danger signal: An auditory signal indicating the onset and, if necessary, the duration and the end of a dangerous situation.

3.1.1 Auditory warning signal (including restart warning signals): Signal indicating the possibility or actual occurrence of a dangerous situation requiring appropriate measures for the elimination or control of the danger and indications concerning the conduct and course of action to be taken.

3.1.2 Auditory emergency evacuation signal: Signal indicating the beginning or the actual occurrence of an emergency involving the possibility of injury and instructing the person(s) to leave the danger zone in the recognized manner.

3.2 Signal reception area: The area where persons are intended to recognize and react to a signal.

NOTE: This standard does not cover problems that might occur from the danger signals being heard from outside the signal reception area.

3.3 Ambient noise: Any sound in the signal reception area not produced by the danger signal transmitter.

3.4 Masked threshold (effective threshold of audibility in noise): The level of sound at which the auditory danger signal is just audible in ambient noise taking into account the hearing deficiencies of the listeners as well as the attenuation of hearing protectors.

4. Symbols

f: Center frequency of a frequency band (e.g. 1/3 octave band)

$L_{W,A}$: A-weighted sound power level of the auditory danger signal (dB)

d: Sound attenuation of the hearing protectors (dB)

$L_{T,oct}$: Octave level of masked threshold (dB)

$L_{T,1/3oct}$: 1/3 octave level of masked threshold (dB)

Sound pressure levels:

L_{oct}: Octave band level (Reference: 20μPa)

$L_{N,A}$: A-weighted level of ambient noise (dB)

$L_{N,oct}$: Octave level of ambient noise (dB)

$L_{N,1/3oct}$: 1/3 Octave level of ambient noise (dB)

$L_{S,A}$: A-weighted sound level of auditory danger signal (dB)

$L_{S,oct}$: Octave level of auditory danger signal (dB)

5. Safety requirements

5.1 General

(1) The nature of the auditory danger signal shall be such that any person in the signal reception area can recognize.
(2) Auditory danger signals shall take precedence concerning recognition over all other auditory signals.
(3) An auditory emergency evacuation signal shall take precedence concerning recognition over all auditory warning signals.
(4) Care shall be taken to review the effectiveness of the auditory danger signal at regular intervals and whenever a new signal (whether a warning signal or not), or noise, is introduced.

5.2 Recognition

The reliable recognition of an auditory danger signal required that the signal be clearly audible, be sufficiently different from other sounds in the environment and have an unambiguous meaning.

5.2.1 Audibility

(1) The signal sound has to be clearly audible. The masked threshold shall be exceeded. Usually this can be achieved of the A-weighted sound level of the signal exceeds the level of ambient noise by 15dB or more.
(2) More accurate predictions can be obtained by the use of octave band analysis or 1/3 octave band analysis.

NOTE: The use of 1/3 octave band analysis gives more precise results, but in most cases octave band analysis is sufficient.

(3) When using octave band analysis, the sound level shall exceed the masked threshold by at least 10dB in one octave band or more in the frequency range given in 8.2.
(4) When using 1/3 octave band analysis, the sound level shall exceed the masked threshold by at least 13bB in one 1/3 octave band or more in the frequency range given in 8.2.
(5) In all cases, the hearing ability of the recipient population and the use of hearing protectors should be taken into account (see 6.2).
(6) Unless there is direct evidence to the contrary, e.g. results of the listening check (see 6.2), the A-weighted sound level of the signal shall be not less than 65bB to ensure its audibility amongst recipients with normal hearing or mild hearing loss.
(7) Where recipients have moderate or severe hearing losses a listening check shall be carried out including a representative sample of these persons, or reliance should not be placed on recognition of the danger signal.

5.2.2 Discriminability

At least two of the acoustic parameters of danger signals (sound level, temporal distribution, combination of frequencies) which influence discriminability of the signals shall be in a dominant way different from those of other signals in the signal reception area and from the ambient noise.

5.2.3 Unambiguity

(1) The meaning of the auditory danger signal shall be unambiguous. Auditory danger signals and signals serving other purposes shall not be similar.
(2) Auditory danger signals from mobile sources of danger shall be generated so as to be audible and recognizable regardless of the speed or number of revolutions of the source.

6. Test methods

6.1 Acoustic measurements

(1) Compliance with the requirements of 5.2 can be checked using measuring equipment; this requires:
   (a) measurement of the A-weighted sound levels of the ambient noise and the signals (this may already be sufficient if the difference between the sound levels is greater than 15dB);
   (b) frequency analysis, if by measurement of the A-weighted sound levels no valid statements can be made;
   (c) measurement of the temporal distribution of the A-weighted sound levels of the auditory danger signal.

(2) Measurements should be made by equipment conforming to ISO 266, IEC 225, and IEC 651 (sound level meters class 2 or better).

(3) For measuring the ambient noise, time weighting "Slow" is to be preferred. In cases of fluctuating noise the maximum value should be taken into account.

6.2 Listening check

To make a listening check at the work place, the following procedures may be used:

(1) From a group of at least 10 test subjects from the signal reception area representing, as far as possible, all age groups present.

(2) Without previous notice, present the auditory danger signal to this group during the most unfavorable situation in the signal reception area (i.e. at the highest level of ambient noise, and possibly during the occurrence of other signals). The test shall be repeated five times.

(3) If necessary, test subjects shall use their own personal noise protection devices.

(4) The auditory danger signal is deemed discriminable if it is recognized by all test subjects.

7. Calculation of effective masked threshold

7.1 The masked threshold can be approximated from the octave band levels LNn,oct or 1/3 octave band levels LNn,1/3oct of the ambient noise in the frequency band n.

The masked threshold $L_{T,oct}$ for octave band analysis is calculated by the following procedures:

Step 1: In the lowest octave band "1"

$$L_{T1,oct}=L_{N1,oct}$$

Step n: (n>1)

$L_{Tn,oct}$=max.($L_{Nn,oct}$ $L_{n-1,oct}$ – 7.5dB)

Repeat step n for n=2… up to the highest octave band.

NOTE: An example for calculation is given in Annex A.

7.2 The masked threshold LT,1/3oct for 1/3 octave band analysis is calculated by the following procedures:

Step 1: In the lowest 1/3 octave band "1"

$L_{T1,1/3oct}$=$L_{N1,1/3oct}$

Step n: (n>1)

$L_{Tn,1/3oct}$=max.($L_{Nn,1/3oct}$ $L_{n-1,1/3oct}$ – 2.5dB)

Repeat step n for n=2… up to the highest octave band.

NOTE: This method may be applied when hearing protectors are being worn, by reducing, in every frequency band, the levels of noise and signal by the relevant mean sound attenuation of the hearing protector.

8. Guidelines for the design of auditory danger signals

8.1 Sound pressure level

(1) Auditory danger signals are usually clearly audible if their A-weighted sound levels exceed the level of ambient noise by 15dB or more and the A-weighted level of the signal is equal to or greater than 65dB.
(2) If the frequency and/or the temporal distribution of the auditory danger signal clearly differ from the corresponding characteristics of the ambient noise, a lower sound pressure level of the signal may be sufficient. This level, however, shall be not less than that specified in 5.2.1.
(3) The sound level of the auditory danger signal should be set so that the signal is clearly recognizable but reactions due to fright are considerably reduced after the sounding of the signal. Reactions due to fright may be expected whenever there is an unexpected steep increase in the sound level.

NOTE: Increase in the sound level by 30dB in 0.5 sec may give fright.

(4) If the A-weighted sound level of the ambient noise in the signal reception area exceeds

110dB the use of additional, rather than solely auditory, danger signals is recommended (e.g. visual danger signals).

8.3 Frequencies

(1) The auditory danger signal should be based on frequencies in the 300-3000 Hz range.
(2) The more the center frequency of the octave band where the danger signal ambient noise is the highest differs from the center frequency of the octave band where the ambient noise is the highest, the easier it is to recognize the danger signal.
(3) The auditory danger signal shall have sufficient energy in the frequency range below 1500 Hz to meet the needs of persons with hearing loss or wearing hearing protectors (see 5.2.1)

8.3 Temporal characteristics

8.3.1 Temporal distribution of the sound level

(1) In general, pulsating auditory signals should be preferred to signals that are constant in time. The pulse repetition frequency shall be in the range from 0.2 Hz to 5 Hz.
(2) The pulse duration and the pulse repetition frequency of the auditory danger signal shall not be identical with the pulse duration and the pulse repetition frequency of a periodically varying ambient noise in the signal reception area.

NOTE: The emergency evacuation signal is a special danger signal. All other danger signal is should differ significantly in their temporal pattern from the emergency evacuation signal.

8.3.2 Temporal distribution of the frequencies

Auditory danger signals whose pitch varies with time are also suitable.

8.4 Duration of the auditory danger signals

Where temporary masking by ambient noise of the auditory danger signal is necessary case shall be taken to ensure that not later than 1 s after the signal has started, the auditory danger signal complies with the requirements of 5.1 and 5.2 for a period of at least 2 s.

ANNEX A

Example of the calculation of the effective masked threshold

Table 1. Calculation of the level of masked threshold for a given octave spectrum

Number of octave band N	Octave band center frequency f (Hz)	Octave level of ambient noise $L_{N,oct}$ (dB)	Intermediate value L_{Tn-1}-7.5dB	Octave level of masked threshold[1] $L_{Tn,oct}$ (dB)
1	125	60	60	60
2	250	70	52.5	70
3	500	58	62.5	62.5
4	1000	71	55	71
5	2000	60	63.5	63.5
6	4000	52	56	56

1) The higher value of the octave level of ambient noise and the intermediate value.

ANNEX B

Examples of warning signals

In the following examples full lines are used for the signal spectra, broken lines for the ambient noise spectra, and dotted lines for the masked threshold where it differs from the noise spectrum.

Example 1: Auditory danger signal indicating approaching shuttle conveyer.

Ambient noise within the signal reception area: sound-insulated axial flow fan.

Characteristics of the ambient noise: not varying in time:

level of ambient noise: $L_{N,A} = 78$ dB

Selected auditory danger signal: $L_{S,A} = 84$ dB

Characteristics of the auditory danger signal: electro-acoustically generated, intermittent signal;

duration ≒ 1 s

The frequency distribution and the temporal distribution of the auditory danger signal and of the ambient noise clearly differ from each other. The auditory danger signal is within a frequency ranger of good audibility. The masked threshold is exceeded by more than 10dB over one octave. The auditory danger signal can thus be easily recognized.

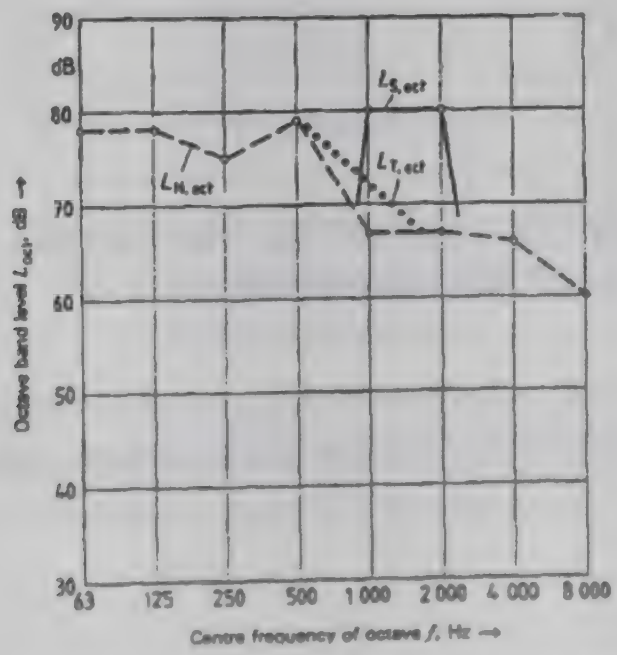


Figure 1. Graph displaying the octave band analysis of the ambient noise, the masked threshold and of the auditory danger signal during the "on" period

Example 2: Auditory danger signal indicating lack of oil in rolling mill

Ambient noise within the signal reception area: Annealing furnaces, rolling mill, removal of scale by means of compressed air.

Characteristics of the ambient noise: Constant in time;

level of ambient noise: $L_{N,A}$=91dB

Selected auditory danger signal: $L_{S,A}$ = 100 dB

Characteristics of the auditory danger signal: hooter (continuous signal), comparable signals do not occur within the signal reception area.

The auditory danger signal exceeds the ambient noise by more than 15 dB within one octave band; comparable signals do not occur. The auditory danger signal can thus be easily recognized.

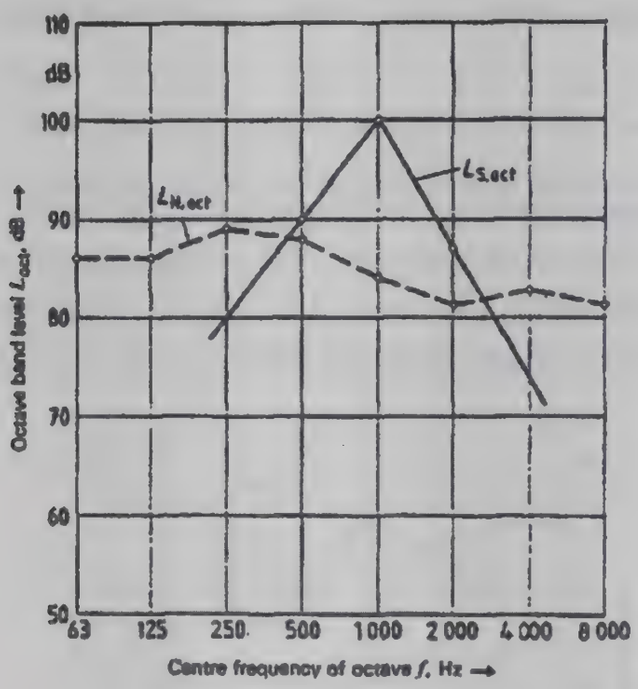


Figure 2. Graph displaying octave band analysis of the ambient noise equal to the masked threshold and of the auditory danger signal

Example 3: Auditory danger signal indicating approaching gantry crane

Ambient noise within the signal reception area:

basic traffic noise: $L_{N1,A} = 54$ dB

crane noise: $L_{N2,A} = 74$ dB

Characteristics of the noise: both varying in time, therefore the A-weighted sound level as well as the octave band level have been set as maximum values using time weighting "Slow".

Selected auditory danger signal: $L_{S,A,Smax} = 90$ dB

Characteristics of the auditory danger signal: ringing bell (low repetition frequency bell).

The auditory danger signal exceeds the ambient noise in A-weighted sound level by more than 15 dB and is in a totally different range of frequencies. It can thus be easily recognized.

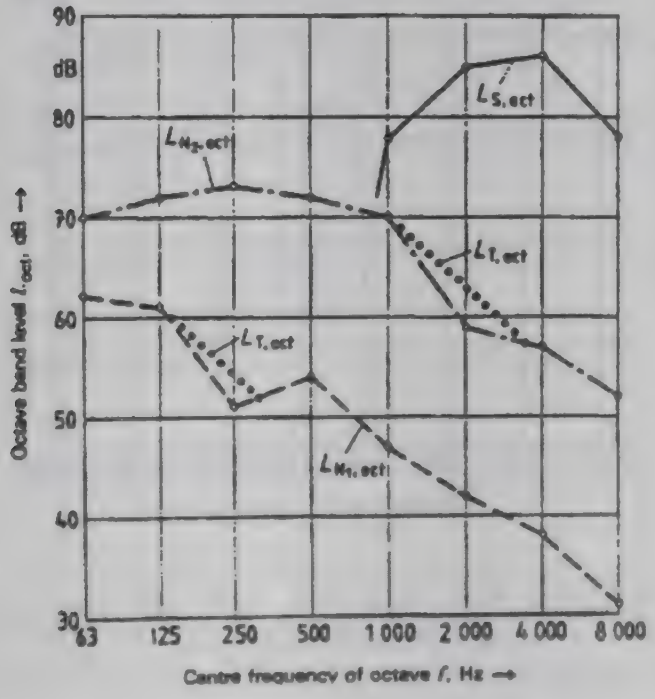


Figure 3. Graph displaying octave band analysis of the basic traffic and crane noise, the masked threshold and of the auditory danger signal

Example 4: Auditory danger signal used in the area of a conveyor

Ambient noise within the signal reception area (operator's cabin): $L_{N,A} = 59$ dB

Selected auditory danger signal: $L_{S,A,} = 80$ dB

Characteristics of the auditory danger signal: bell (high repetition frequency).

Because of the frequencies involved, the difference in noise levels between the auditory danger signal and the ambient noise, and their different temporal distributions, the auditory danger signal can be easily recognized, on condition that there are no other major noise sources.

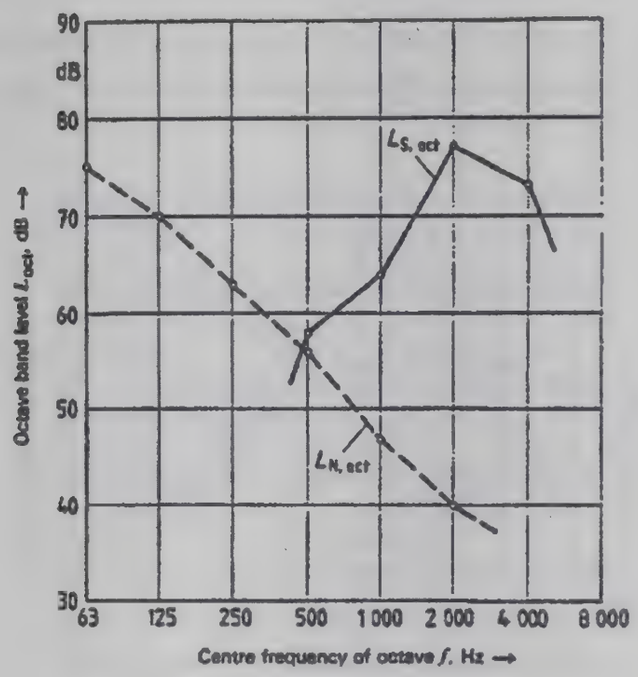


Figure 4. Graph displaying octave band analysis of ambient noise equal to the masked threshold and of the auditory danger signal

Example 5: Auditory danger signal indicating approaching railway track ballast cleaning apparatus within an industrial plant

Ambient noise in the signal reception area: $L_{N,A} = 94$ dB

Selected auditory danger signal: $L_{S,A,} = 100$ dB

Characteristics of the auditory danger signal:

horn signal;

the basic frequency in the 250 Hz band;

duration of each pulse approximately 2 s.

The frequency distribution and the temporal distribution of the auditory danger signal and the ambient noise clearly differ from each other. The masked threshold is exceeded by more than 10 dB over two octaves. The auditory danger signal can thus be easily recognized.

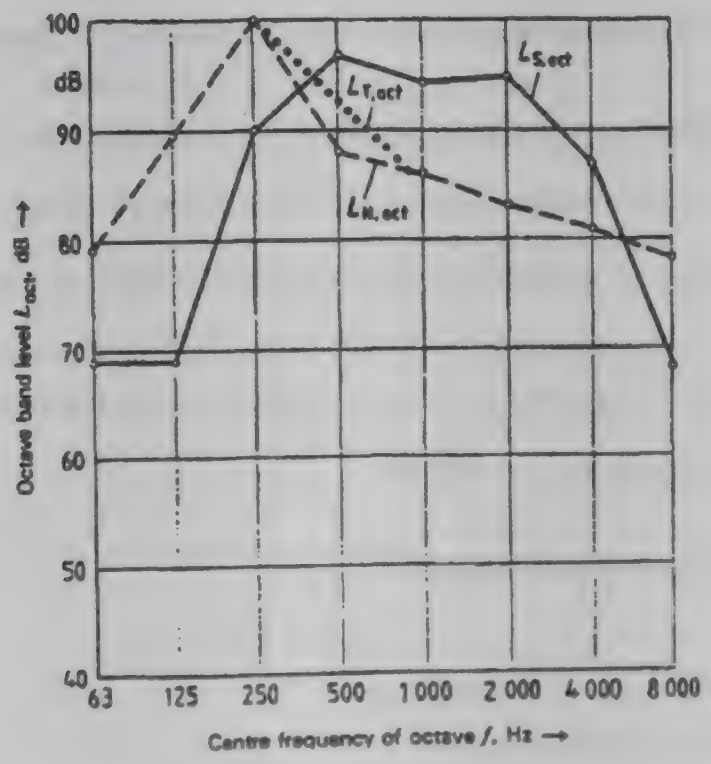


Figure 5. Graph displaying octave band analysis of the ambient noise, the masked threshold and of the auditory danger signal

Example 6: Auditory danger signal of Example 5, when a hearing protector is worn

NOTE: In cased where hearing protectors are worn, the listening check (see 6.2) is preferable to the calculation method since individual sound attenuation is taken into account. Calculation methods are preferable for selecting the type of hearing protector in a specific signal and noise configuration.

A hearing protector for the given ambient noise might have the following mean attenuation values as given in Table 2.

Table 2. Mean attenuation data of a hearing protector (according to ISO 4869-1)

f (Hz)	63	125	250	500	1000	2000	4000	8000
di (dB)	21	27	26	28	29	30	43	33

Calculation of the effective octave band levels under the hearing protector, where:

$L'_{N,oct}$: the calculated effective octave band level of the ambient noise $L_{N,oct,i}$-d_i

$L'_{S,oct}$: the calculated effective octave band level of the auditory danger signal $L_{S,oct,i}$-d_i

$L'_{T,oct}$: the octave band level of masked threshold under the hearing protector.

The masked threshold $L'_{T,oct}$ is exceeded by 12 dB in the 2000 Hz octave band. The auditory danger signal can be easily recognized even by persons wearing the hearing protector.

Selected auditory danger signal: $L_{S,A,}$ = 100 dB

Characteristics of the auditory danger signal:

horn signal;
the basic frequency in the 250 Hz band;
duration of each pulse approximately 2 s.

The frequency distribution and the temporal distribution of the auditory danger signal and the ambient noise clearly differ from each other. The masked threshold is exceeded by more than 10 dB over two octaves. The auditory danger signal can thus be easily recognized.

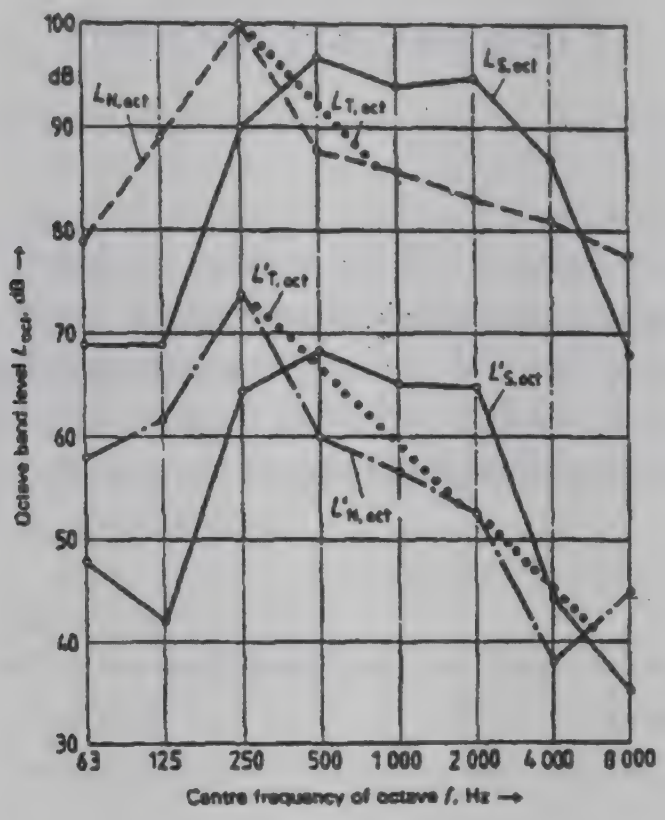


Figure 6. Graph displaying octave band analysis of the ambient noise, the masked threshold and the auditory danger signal (above) and the effective levels under the hearing protector (below).

Pressure Equipment

1. Purpose

This standard, based on the Directive 97/23/EC, specifies the design, manufacture, and conformity of assessment of pressure equipment, according to Article 34-2 of the Industrial Safety and Health Act, Article 59-3 of the Enforcement Decree of the Industrial Safety and Health Act, and Article 4 of the Safety Certification Regulation for Machinery and Equipment (Notification No. 2003-15 of the Ministry of Labor).

2. Scope

This standard applies to pressure equipment and assemblies with a maximum allowable pressure greater than 0.5 bar.

3. Definitions

For the purpose of this standard, the following terms and definitions apply.

3.1 Pressure equipment: Vessels, piping, safety accessories, and pressure accessories.

3.2 Vessel: A housing designed and built to contain fluids under pressure including its direct attachments up to the coupling point connecting it to other equipment. A vessel may be composed of more than one chamber.

3.3 Piping: piping components intended for the transport of fluids, when connected together for integration into a pressure system. Piping includes in particular a pipe or system of pipes, tubing, fittings, expansion joints, hoses, or other pressure-bearing components.

3.4 Safety accessories: Devices designed to protect pressure equipment against the allowable limits being exceeded. Such devices include:

(1) devices for direct pressure limitation, such as safety valves and bursting disc safety devices;
(2) devices for monitoring and control of pressure equipment, such as pressure switches, temperature switches, and safety related measurement control and regulation devices.

3.5 Pressure accessories: Devices with an operational function and having pressure-bearing housings.

3.6 Assemblies: Several pieces of pressure equipment assembled to constitute an integrated

and functional whole.

3.7 Pressure: Pressure relative to atmospheric pressure, i.e. gauge pressure.

3.8 Maximum allowable pressure: Maximum pressure for which the equipment is designed.

3.9 Maximum allowable temperature: Maximum temperature for which the equipment is designed, as specified by the manufacturer.

3.10 Minimum allowable temperature: Minimum temperature for which the equipment is designed, as specified by the manufacturer.

3.11 Volume: Internal volume of a chamber.

3.12 Nominal size: A numerical designation of size which is common to all components in a piping system other than components indicated by outside diameters or by thread size.

3.13 Fluids: Gases, liquids, and vapors in pure phase as well as mixtures thereof. A fluid may contain a suspension of solids.

3.14 Permanent joints: Joints that cannot be disconnected except by destructive methods.

4. General safety requirements

4.1 General

4.1.1 Pressure equipment shall be designed, manufactured, and checked, and if applicable equipped and installed, in such a way as to ensure its safety when put into service in accordance with the manufacturer's instructions, or in reasonably foreseeable conditions.

4.1.2 In choosing the most appropriate solutions, the manufacturer shall apply the principles set out below in the following order:

(1) eliminate or reduce hazards as far as is reasonably practicable;
(2) apply appropriate protection measures against hazards that cannot be eliminated;
(3) where appropriate, inform users of residual hazards and indicate whether it is necessary to take appropriate special measures to reduce the risks at the time of installation and or use.

4.1.3 Where the potential for misuse is known or can be clearly foreseen, the pressure equipment shall be designed to prevent danger from such misuse, or, if that is not possible, adequate warning given that the pressure equipment shall be not be used in that way.

4.2 Design

4.2.1 General

The pressure equipment shall be properly designed taking into account all relevant factors in order to ensure that the equipment will be safe throughout its intended life. The design shall incorporate appropriate safety coefficients using comprehensive methods that are known to incorporate adequate safety margins against all relevant failure.

4.2.2 Design for adequate strength

4.2.2.1 The pressure equipment shall be designed for loadings appropriate to its intended use and other reasonably foreseeable operating conditions. In particular, the following factors shall be taken into account:

(1) internal/external pressure;
(2) ambient and operational temperatures;
(3) static pressure and mass of contents in operating and test conditions;
(4) traffic, wind, earthquake loading;
(5) reaction forces and moments which result from the supports, attachments, piping, etc.;
(6) corrosion and erosion, fatigue, etc.;
(7) decomposition of unstable fluids;
(8) various loadings which can occur at the same time, and the possibility of their simultaneous occurrence.

4.2.2.2 Design for adequate strength shall be based on:

(1) a calculation method, as described in 4.2.2.3, and, if necessary, an experimental design method as described in 4.2.2.4;
(2) an experimental design method without calculation, as described in 4.2.2.4, when the product of the maximum allowable pressure and the volume is less than 6,000 bar·ℓ or the product of the maximum allowable pressure and the nominal size is less than 3,000 bar.

4.2.2.3 Pressure containment and other loading aspects

(1) The allowable stresses for pressure equipment shall be limited having regard to reasonably foreseeable failure modes under operating conditions. In addition, safety factors shall be applied to eliminate fully any uncertainty arising out of manufacture, actual operational conditions, stresses, calculation models, and the properties and behavior of the material.
(2) These calculation methods shall provide sufficient safety margins consistent, where

applicable, with the requirements of 5.3.

(3) The requirements set out above may be met by applying one of the following methods, as appropriate, if necessary as a supplement to or in combination with another method:
(a) design by formula; (b) design by analysis;(c) design by fracture mechanics.

(4) Resistance
The following requirements shall be taken into account in the design calculations to establish the resistance of the pressure equipment.
(a) The calculation pressures shall not be less than the maximum allowable pressures and take into account static head and dynamic fluid pressures and the decompressions of unstable fluids. Where a vessel is separated into individual pressure-containing chambers, the partition wall shall be designed on the basis of the highest possible chamber pressure relative to the lowest pressure possible in the adjoining chamber.
(b) The calculation temperatures shall allow for appropriate safety margins.
(c) The maximum stresses and peak stress concentrations shall be kept within safe limits.
(d) The calculation for pressure containment shall utilize the values appropriate to the properties of the material, based on documented data, having regard to the provisions set out in 4.4 together with appropriate safety factors. Material properties to be considered include:
- yield strength, 0.2% or 1.0% proof strength; - tensile strength; - creep strength; - fatigue data; - Young's modulus (modulus of elasticity); - appropriate amount of plastic strain; - impact strength; - fracture toughness; - appropriate joint factors depending on the type of non-destructive testing, the materials jointed, and the operating conditions.
(e) The design shall take appropriate account of all reasonably foreseeable degradation mechanisms (e.g. corrosion, creep, fatigue).
(f) Attention shall be drawn, in the instructions refereed to in 4.3.4, to particular features of the design that are relevant to the life of the equipment.

(5) Stability aspects

Where the calculated thickness does not allow for adequate structural stability, the necessary measures shall be taken to remedy the situation taking into account the risks from transport and handling.

4.2.2.4 Experimental design method

(1) The design of the equipment may be validated, in all or in part, by an appropriate test program carried out a sample representative of the equipment or the category of equipment.
(2) The test program shall define test conditions and criteria for acceptance or refusal.
(3) The actual values of the essential dimensions and characteristics of the materials that

constitute the equipment tested shall be measured before the test.

(4) During tests, it shall be possible to observe the critical zones of the pressure equipment with adequate instrumentation capable of registering strains and stresses with sufficient precision.

(5) The test programs shall include:

(a) a pressure strength test, the purpose of which is to check that, at a pressure with a defined safety margin in relation to the maximum allowable pressure, the equipment does not exhibit significant leaks or deformation exceeding a determined threshold. The test pressure shall be determined on the basis of the differences between the values of the geometrical and material characteristics measures under test conditions and the values used for design purposes;

(b) where the risk of creep or fatigue exists, appropriate tests determined on the basis of the service conditions laid down for the equipment, for example hole time at specified temperatures, number of cycles at specified stress-levels, etc.;

(c) where necessary, additional tests concerning other factors such as corrosion, external damage, etc.

4.2.3 Provisions to ensure safety handling and operation

4.2.3.1 The method of operation specified for pressure equipment shall be such as to preclude any reasonably foreseeable risk in operation of the equipment. Particular attenuation shall be paid to:

(1) closures and openings;
(2) dangerous discharge of pressure relief blow-off;
(3) devices to prevent physical access whilst pressure or a vacuum exists;
(4) surface temperature taking the intended use into account;
(5) decomposition of unstable fluids.

4.2.3.2 Pressure equipment fitted with an access door shall be equipped with an automatic or manual device enabling the user easily to ascertain that the opening will not present any hazard. Where the opening can be operated quickly, the pressure equipment shall be fitted with a device to prevent it being opened whenever the pressure or temperature of the fluid presents a hazard.

4.2.4 Examination methods

4.2.4.1 Pressure equipment shall be designed and constructed so that all necessary examinations to ensure safety can be carried out.

4.2.4.2 Access openings allowing physical access to the inside of the pressure equipment

shall be constructed so that appropriate examinations can be carried our safely.
4.2.4.3 Other methods of ensuring the safe condition of the pressure equipment may be applied:

(1) where it is too small for physical internal access, or (2) where opening the pressure equipment would adversely affect the inside, or(3) where the substance contained has been shown not to be harmful to the material from within the pressure equipment is made and no other internal degradation mechanisms are reasonably foreseeable.

4.2.5 Methods of draining and venting

Adequate methods shall be provided for the draining and venting of pressure equipment to avoid harmful effects such as water hammer, vacuum collapse, corrosion and uncontrolled chemical reactions and to permit cleaning, inspection, and maintenance in a safe manner.

4.2.6 Corrosion

Where necessary, adequate allowance or protection against corrosion shall be provided, taking due account of the intended and reasonably foreseeable use.

4.2.7 Wear

Where severe conditions of erosion or abrasion may arise, adequate measures shall be taken to minimize the effect by appropriate design, e.g. additional material thickness, or by the use of liners or cladding materials. Attentions shall be drawn, in the instructions referred to in 4.3.4, to measures necessary for continued safe use.

4.2.8 Assemblies

Assemblies shall be so designed that the components are suitable and reliable for their duty and properly integrated and assembled in an appropriate manner.

4.2.9 Provisions for filling and discharge

Where appropriate, the pressure equipment shall be so designed and provided with accessories as to ensure safe filling and discharge in particular with respect to hazards:

(1) on filling: over filling or over pressurization having regard to the filling ratio and to vapor pressure at the reference temperature;
(2) on filling: instability of the pressure equipment;
(3) on discharge: the uncontrolled release of the pressurized fluid;
(4) on filling or discharge: unsafe connection and disconnection.

4.2.10 Protection against exceeding the allowable limits of pressure equipment

4.2.10.1 Where the allowable limits could be exceeded under reasonably foreseeable, the pressure equipment shall be fitted with, or provision made for the fitting of, suitable protective devices, unless the equipment is intended to be protected by other protective devices within an assembly. The suitable device or combination of such devices shall be determined on the basis of the particular characteristics of the equipment or assembly.

4.2.10.2 Suitable protective devices and combinations thereof comprise:

(1) safety accessories as defined in 3.4;
(2) adequate monitoring devices such as indicators and/or alarms which enable adequate action to be taken either automatically or manually to keep the pressure equipment within the allowable limits.

4.2.11 Safety accessories

4.2.11.1 Safety accessories shall:

(1) be so designed and constructed as to be reliable and suitable for their intended duty and take into account the maintenance and testing requirements of the devices, where applicable;
(2) be independent of other functions, unless their safety function cannot be affected by such other functions;
(3) comply with appropriate design principles, including fail-safe modes, redundancy, diversity, and self-diagnosis, to obtain suitable and reliable protection.

4.2.11.2 Pressure limiting devices

These devices shall be so designed that the pressure will not permanently exceed the maximum allowable pressure. However, a short duration pressure surge in keeping with the specifications laid down in 5.3.3 is allowable.

4.2.11.3 Temperature monitoring devices

These devices shall have an adequate response time on safety grounds, consistent with the measurement function.

4.2.12 External fire

Where necessary, pressure equipment shall be so designed and, where appropriate, fitted with suitable accessories, or provision made for their fitting, to meet damage-limitation requirements in the event of external fire.

4.3 Manufacturing

4.3.1 The manufacturer shall ensure the competent execution of the provisions set out at the design stage by applying the appropriate techniques and relevant procedures.

4.3.1.1 Preparation of the component parts

Preparation of the component parts (e.g. forming and chamfering) shall not give rise to defects or cracks or changes in the mechanical properties likely to be detrimental to the safety of the pressure equipment.

4.3.1.2 Permanent joining

(1) Permanent joints and adjacent zones shall be free of any surface or internal defects.
(2) The properties of permanent joints shall meet the minimum properties specified for the materials to be joined unless other relevant property values are specifically taken into account in the design calculation.
(3) For pressure equipment, permanent joining of components which contribute to the pressure resistance of equipment and components which are directly attached to them must be carried out by suitably qualified personnel according to suitable operating procedures.

4.3.1.3 Non-destructive tests

For pressure equipment, non-destructive tests of permanent joints shall be carried out by suitable qualified personnel.

4.2.1.4 Heat treatment

Where there is a risk that the manufacturing process will change the material properties to an extent which would impair the safety of the pressure equipment, suitable heat treatment must be applied at the appropriate stage of manufacture.

4.3.1.5 Traceability

Suitable procedures shall be established and maintained for identifying the material making up the components of the equipment that contribute to pressure resistance by suitable means from receipt, through production, up to the final test of the manufactured pressure equipment.

4.3.2 Final assessment

Pressure equipment shall be subjected to final assessment as described below

4.3.2.1 Final inspection

(1) Pressure equipment shall undergo a final inspection to assess visually and by examination of the accompanying documents compliance with the requirements of the Safety Certification Standard.
(2) Where examination during the final inspection is no longer possible, the final inspection must be carried out internally and externally on every part of the equipment in the course of manufacture.

4.3.2.2 Proof test

(1) Final assessment of pressure equipment shall include a test for the pressure containment aspect at a pressure at least equal to the value laid down in 5.3.4.
(2) Where the pressure test is not practical, other tests may be carried out.
(3) For tests other than the pressure test, additional measures, such as non-destructive tests, shall be applied before those tests are carried out.

4.3.2.3 Inspection of safety devices

For assemblies, the final assessment shall also include a check of the safety devices intended to check full compliance with the requirements referred to in 4.2.10.

4.3.3 Marking and labeling

4.3.3.1 In addition to the S mark, the following information shall be provided:

(1) the name and address of the manufacturer;
(2) the year of manufacturer;
(3) identification of the pressure equipment according to its nature, such as type, model, and serial number;
(4) maximum/minimum allowable limits;
(5) depending in the type of pressure equipment, further information necessary for safe installation, operation or use and, where applicable, maintenance and periodic inspection such as: - the volume of the pressure equipment in ℓ - the nominal size for piping; - the test pressure applied in kgf/cm2 and data; - safety device set pressure in kgf/cm2 or bar; - output of the pressure equipment in kW; - supply voltage in V; - intended use; - filling ratio in kg/ℓ - maximum filling mass in kg; - tare mass in kg; - the product group;
(6) warnings fixed to the pressure equipment drawing attention to misuse.

4.3.3.2 The S mark and the required information shall be given on the pressure equipment or on a data plate firmly attached to it, with the following exceptions:

(1) appropriate documentation may be used to avoid repetitive marking of individual parts intended for the same assembly;
(2) where the pressure equipment is too small, e.g. accessories, the information referred to in 4.3.3.1 (5) may be given on a label attached to the pressure equipment;
(3) labeling or other adequate measures may be used as the warnings referred to in 4.3.3.1 (6).

4.3.4 Operating instructions

4.3.4.1 The manufacturer of pressure equipment shall provide users with operating instructions, containing all the necessary safety information relating to:

(1) mounting including assembling of different pieces of pressure equipment;
(2) putting into service;
(3) use;
(4) maintenance including checks by the user.

4.3.4.2 Instructions shall cover information affixed to the pressure equipment in accordance with 4.3.3, with the exception of serial identification, and shall be accompanied, where appropriate, by the technical documents, drawings, and diagrams necessary for a full understanding of these instructions.

4.3.4.3 These instructions shall also refer to hazards arising from misuse in accordance with

4.1.3 and particular features of the design in accordance with 4.2.2.3.

4.4 Materials

Materials used for pressure equipment shall be suitable for such application during the scheduled lifetime. Welding consumables and other joining materials need fulfill only the relevant requirements of 4.4.1, 4.4.2.1, and 4.4.3.1.

4.4.1 Materials for pressurized parts

4.4.1.1 The materials for this application shall have appropriate properties for all operating and test conditions, and in particular they should be sufficiently ductile and tough.

(1) The properties of the materials shall comply with the requirements in 5.3.5.
(2) Special care shall be exercised in particular in selecting materials to prevent brittle-type fracture.
(3) Where for specific reasons brittle material has to be used, appropriate measures shall be taken.

4.4.1.2 The materials shall sufficiently have chemical resistance to the fluid contained in the pressure equipment, and shall not be significantly affected within the scheduled lifetime of the equipment.

4.4.1.3 The materials shall not be significantly affected by ageing.

4.4.1.4 The materials shall be suitable for the intended processing procedures.

4.4.1.5 When various materials are put together, they shall be selected in order to avoid significant undesirable effects.

4.4.2 Use of appropriate materials

4.4.2.1 The pressure equipment manufacturer shall define in an appropriate manner the values necessary for the design calculations referred to in 4.2.2.3 and the essential characteristics of the materials and their treatment referred to in 4.4.1.

4.4.2.2 The manufacturer shall provide in his technical documents relating to compliance with the materials specifications of the Safety Certification Standard, in one of the following forms:

(1) by using materials that comply with KS standards;
(2) by using materials approved for pressure equipment by a certified material analysis and test organization;
(3) by a particular material appraisal.

4.4.3 Measures to be taken by the manufacturer

4.4.3.1 The manufacturer shall take appropriate measures to ensure that the material used conforms with the required specification. In particular, documentation prepared by the material manufacturer affirming compliance with a specification must be obtained for all materials.

4.4.3.2 The manufacturer shall have its own quality assurance system. In particular, a standard quality manual shall be prepared to obtain reliable and consistent quality of welding processes. The welding shall be carried out by only suitably qualified personnel.

5. Specific requirements for pressure equipment

In addition to the applicable requirements of 4.1 and 4.4, the following requirements apply to the pressure equipment covered by 5.1 and 5.2.

5.1 Fired or heated pressure equipment with a risk of overheating

5.1.1 This type of pressure equipment includes:

(1) steam and hot water generators: fired or heated pressure equipment with a risk of overheating intended for generation of steam or super-heated water at temperatures higher than 100℃ having a volume greater than 2ℓ(e.g. fired steam and hot-water boilers, superheaters and reheaters, waste-heat boilers, waste incineration boilers, electrode or immersion-type electrically heated boilers, pressure cookers, together with their accessories, the systems for treatment of feedwater or fuel supply);
(2) process-heating equipment: for other than steam and hot-water generation (e.g. heaters for chemical and other similar processes and pressurized food-processing equipment).

5.1.2 This pressure equipment must be calculated, designed, and constructed so as to avoid to minimize risks of a significant loss of containment from overheating. In particular, it shall be ensured, where applicable, that:

(1) appropriate means of protection are provided to restrict operating parameters such as heat input, heat take-off, and fluid level so as to avoid any risk of local and general overheating;
(2) sampling points are provided where required to allow evaluation of the properties of the fluid so as to avoid risks related to deposits and/or corrosion;
(3) adequate provisions are made to eliminate risks of damage from deposits;
(4) means of safe removal of residual heat after shutdown are provided;
(5) steps are taken to avoid a dangerous accumulation of ignitable mixture of combustible substances and air, or flame blowback.

5.2 Piping

Design and construction of piping shall ensure:

5.2.1 that the risk of over stressing from inadmissible free movement or excessive forces being produced, e.g. on flanges, connections, bellows or horses, is adequately controlled by means such as supports, constraint, anchoring, alignment, and pre-tension;

5.2.2 that where there is a possibility of condensation occurring inside pipes of gaseous fluids, means are provided for drainage and removal of deposits from low areas to avoid damage from water hammer or corrosion;

5.2.3 that proper consideration is given to the potential damage from turbulence and formation of vortices;

5.2.4 that due consideration is given to the risk of fatigue due to vibrations in pipes;

5.2.5 that, where fluids are contained in the piping, appropriate means are provided to isolate 'take-off' pipes the size of which represents a significant risk;

5.2.6 that the risk of inadvertent discharge is minimized; the take-off points must be clearly marked on the permanent side;

5.2.7 that the position and route of underground piping is at least recorded in the chemical documentation to facilitate safe maintenance, inspection, or repair.

5.3 Specific quantitative requirements for certain pressure equipment

The following provisions apply as a general rule. However, where they are not applied, including the cases where are not specifically referred to and no harmonized standards are applied, the manufacturer must demonstrate that appropriate measures have been taken to achieve an equivalent overall level of safety.

5.3.1 Allowable stresses

5.3.1.1 Symbols

Yield limit, Re/t, indicates the value at the calculation temperature of:

(1) the upper flow limit for a material presenting upper and lower flow limits;
(2) the 1.0% proof strength of austenitic steel and non-alloyed aluminum;
(3) the 0.2% proof strength in other cases.

$R_{m/20}$ means the minimum value of the ultimate strength 20℃.

$R_{m/r}$ designates the ultimate strength at the calculation temperature.

5.2.1.2 The permissible general membrane stress for predominantly static loads and for temperatures outside the range in which creep is significant must not exceed the smaller of the following values, according to the material used:

(1) in the case of ferric steel including normalized steel and excluding fine-grained steel and specially heat-treated steel, 2/3 of $R_{e/t}$ and 5/12 of $R_{m/20}$
(2) in the case of austenitic steel: - if its elongation after rupture exceeds 30%, 2/3 f $R_{e/r}$- or, alternatively, and if its elongation after rupture exceeds 35%, 5/6 of $R_{e/t}$ and 1/3 of $R_{m/r}$;
(3) in the case of non-alloy or low-alloy cast steel, 10/19 of $R_{e/t}$ and 1/3 of $R_{m/20}$
(4) in the case of aluminum, 2/3 of $R_{e/t}$
(5) in the case of aluminum alloys excluding precipitation hardening alloys, 2/3 of $R_{e/t}$ and

5/12 of $R_{m/20}$.

5.3.2 Joint coefficients

For welded joints, the joint coefficient shall not exceed the following values:

(1) for equipment subject to destructive and non-destructive tests which confirm that the whole series of joints show no significant detects: 1,
(2) for equipment subject to random non-destructive testing: 0.85;
(3) for equipment not subject to non-destructive testing other than visual inspection: 0.7.

If necessary, the type of stress and the mechanical and technological properties of the joint shall also be taken into account.

5.3.3 Pressure limiting devices for pressure vessels

The momentary pressure surge referred to in 4.2.11.2 shall be kept to 10% of the maximum allowable pressure.

5.3.4 Hydrostatic test pressure

For pressure vessels, the hydrostatic test pressure referred to in 4.3.2.2 shall:

(1) for steel or non-ferrous metal: exceed the maximum allowable pressure (design pressure)×1.5; taking into account temperature;
(2) for other materials: comply with the Industrial Safety and Health Act (Notification No. 1997-34 of the Ministry of Labor).

5.4 Material properties

Unless other values are required in accordance with other criteria that must be taken into account, a steel is considered as sufficiently ductile to satisfy 4.4.1.1, if, in a tensile test carried out by a standard procedure, its elongation after rupture is no less than 14% and its bending rupture energy measured with a V-test piece on KS D 0048 is no less than 27J, at a temperature not greater than 20℃ but not higher than the lowest schedules operating temperature.

Flat Woven Webbing Slings Made of Man-Made Fibers

1. Purpose

This standard specifies the requirements related to safety of and methods of testing flat woven webbing slings made of man-made fibers (hereinafter referred to as "flat woven webbing slings"), according to Article 34-2 of the Industrial Safety and Health Act, Article 59-3 of the Enforcement Decree of the Industrial Safety and Health Act, and Article 4 of the Safety Certification Regulation for Machinery and Equipment (Notification No. 2003-15 of the Ministry of Labor).

2. Scope

This standard applies to the flat woven webbing slings made of man-made fibers, e.g. polyamide, polyester and polypropylene man-made fibers or those with equivalent performance, which are intended for general purpose lifting operations.

3. Definitions

For the purpose of this standard, the following terms and definitions apply.

3.1 Flat woven webbing sling: Flexible sling consisting of a sewn webbing component for attaching loads to the hook of a crane or other lifting machine.

3.2 Webbing: That woven from industrial yarns in the form of a web.

3.3 Multi-layer sling: Flat woven webbing sling, the sewn webbing component or components of which consist of two or more layers of identical webbings superimposed in the lengthwise direction.

3.4 Seam: A method of securing the webbing to itself, securing several webbings to each other, or securing reinforcements to the webbing by means of stitches produced by the thread traversing the layers.

3.5 Eye: A termination of a sewn webbing component, produced by turning the end of the webbing through 180° and securing it to the standing part of the webbing, so forming a terminal soft eye or attaching a terminal fitting.

3.6 Fitting: A load-bearing metal component, supplied as part of a sling and which is used to terminate the sling so as to allow it to be reeved, attached to other lifting accessories, connected to other flat woven webbing slings to form a multi-leg sling assembly or connected

to the hook of a crane or other lifting machine.

3.7 Nominal length: specified length of the sling, inclusive of fittings, from bearing point to bearing point.

3.8 Effective working length (EWL): Actual finished length (ℓ1)of the flat woven webbing sling, inclusive of fittings, from bearing point to bearing point (see Table 1, 2 and 3).

3.9 Basic working load: Maximum load that the sewn webbing component of a flat woven webbing sling can sustain in straight pull.

3.10 Working load limit (WLL): Maximum mass that a sling or sling assembly is authorized to sustain in general lifting service.

4. Safety requirements

4.1 Materials

The webbing shall be woven wholly from industrial yarns and have a tenacity of not less than 60 cN/tex (tex: the weight in grams of 1,000 m of yarn), from one of the following materials:

(1) polyamide (PA), high tenacity multi-filament;
(2) polyester (PES), high tenacity multi-filament;
(3) polypropylene (PP), high tenacity multi-filament;
(4) other high tenacity multi-filament with quality equivalent to (1)-(3).

4.2 Weaving

Weaving for flat woven webbing slings shall meet the following requirements:

(1) All yarns shall be of identical parent material;
(2) When a sample is tested in accordance with Annex A, the width of the finished sling shall change as follows: - for widths less than or equal to 100 mm: no more than –10% - for widths over 100 mm: no more than –12%.

4.3 Width

The width of the woven webbing shall not be less than 25 mm and shall not exceed 450 mm, and the tolerance shall not be more than: (1) ±10% for nominal widths less than or equal to 100 mm; (2) ±8% for nominal widths greater than 100 mm.

4.4 Webbing thickness and sling thickness

For single layer flat woven webbing slings, the load-bearing element of the sling shall have a minimum thickness of 2 mm. For multi-layer slings, the webbing shall have a minimum thickness of 1.2 mm.

4.5 Sling types and designation

The types and designation of flat woven webbing slings are shown in Table 1, 2, and 3.

Table 1. Endless flat woven webbing slings

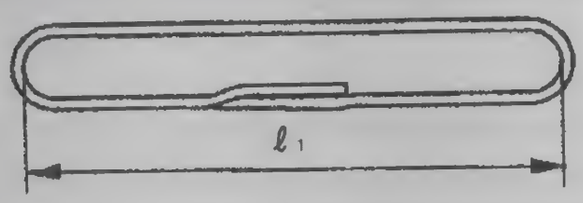
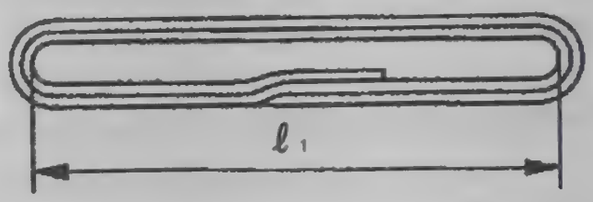
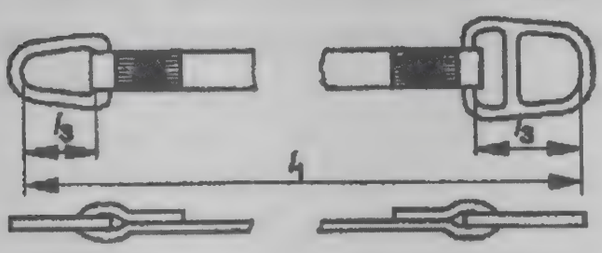
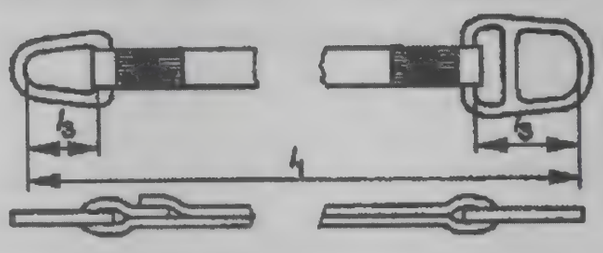
Endless, single-layer sling	Endless, two-layer sling
	

Table 2. Flat woven webbing slings with eyes

Single-layer sling with eyes	Two-layer sling with eyes
	

Table 3. Flat woven webbing slings with fittings

Single-layer sling with fittings	Two-layer sling with fittings
	
 (Single sling with fittings)	 (Single sling with reevable fittings)

4.6 Effective working length (EWL)

The effective working length (EWL), ℓ_1, of a flat woven webbing sling shall not differ from the nominal length by more than 3%.

4.7 Sewing of slings

4.7.1 All seems shall be made from thread of identical parent material as the webbing and shall be made with a locking stitch machine.

4.7.2 Stitches shall not touch or affect the edges of the webbing except those which secure the eye durability reinforcement.

4.7.3 The stitches of the seam shall traverse the parts of the webbing to be sewn together, and the stitching shall lay flat and not have loops above the surface of the webbing.

4.7.4 The ends of cut webbing shall be treated in such a way (e.g. fused by heating) as to prevent unravelling. Treatment of cut ends by heating shall not damage adjacent stitching, and heat-treated ends shall not be oversewn.

4.8 Soft eye

The inside length, ℓ_1, of the eyes (see Table 2) shall be of the following minimum dimensions:

(1) three times the width of the webbing for width of up to 150 mm;
(2) two and a half times the width of the webbing for widths greater than 150 mm.

4.9 Reinforcement of soft eyes

Soft eyes shall be reinforced to protect the inner surface of the eye against damage during lifting operations; suitable reinforcing materials include a sleeve or piece of webbing or leather or other durable material.

5. Fittings

If the fittings are supplied as part of a sling, the following requirements shall be met:

5.1 The seating of a fitting in contact with the webbing shall be so finished that, when tested in accordance with Annex A, there shall be no damage to the area of webbing in contact with the fitting.

5.2 Welded fittings shall be placed so that the welds remain visible when the sling is in use.

5.3 Appropriate measures shall be taken to protect the sling against the damage by any edge part of the fittings.

6. Design requirements

The fracture strength of flat woven webbing slings without fittings shall be at least 7 times the basic working load.

7. Testing

7.1 Tensile test

7.1.1 Flat woven webbing slings without fittings shall be tested according to the requirements below.

(1) The test shall be in accordance with Annex A.
(2) If, during testing, the sewn webbing component does not sustain a force equivalent to seven times the basic working load, but sustains a load of not less than 90% of the force, these further samples of the same type shall be tested. If one or more of these samples does not sustain the force equivalent to seven times the basic working load, slings of this type shall be deemed not to comply with this standard.
(3) The number of samples shall be at least 3.

7.1.2 Flat woven webbing slings with fittings shall be tested according to the requirements below.

(1) The test shall be in accordance with Annex A.
(2) If, during testing, the sewn webbing component does not sustain a force equivalent to five times the basic working load, but sustains a load of not less than 90% of the force, these further samples of the same type shall be tested. If one or more of these samples does not sustain the force equivalent to five times the basic working load, slings of this type shall be deemed not to comply with this standard.
(3) The number of samples shall be at least 3.

7.2 Testing intervals

The test shall be carried out at least at the intervals shown in Table 4 or every 1 year, whichever is the sooner, in accordance with the Annex A.

Table 4. Testing intervals

Basic working load of sewn webbing component	Maximum quantity per type between tests
Up to and including 3 t	500
Over 3 t	250

8. Marking

The marking of the sling shall include at least the following:

(1) the basic working load;
(2) the working load limit;
(3) the nominal length;
(4) the material of the webbing;
(5) the working load limit of the fittings;
(6) the manufacturing date;
(7) the manufacturer's name;
(8) the code;
(9) the standard;
(10) the types and designation;
(11) Safety Certification Mark

9. Instructions for use

The manufacturer shall provide a user or purchaser with manual or instructions for use containing the environment, methods, and cautions for use and the criteria for the disposal.

ANNEX A

Test methods

A.1 General

A.1.1 During load tests, the force shall be applied so that the elongation of the specimen takes place at a maximum rate of 110 mm/min per 1,000 mm length of the specimen.

A.1.2 The specimen shall not be pre-loaded prior to testing.

A.2 Test to determine the change in webbing width under load

A.2.1 The specimen shall be mounted in the test machine and arranged so that it is under lo load, bur form a gentle catenary.

A.2.2 A mark shall be placed across the face of the webbing, normal to the longitudinal axis, at the mid-point of the specimen. A further mark shall be placed each side of the center mark mid way between the central mark and bearing point of the specimen, thus dividing it into four parts of equal length.

1: Mid point
2: Dividing marks
3: Bearing point of specimen

Figure A. Position of marking to divide the specimen into four equal parts

A.2.3 The width of the webbing shall be measured at each of the marks to the nearest millimeter, and each of these measurements shall be recorded as W_1.

A.2.4 The specimen shall then be subjected to a force equivalent to twice the basic working load.

A.2.5 While this force is maintained the width of the webbing shall be measured at each of the marks to the nearest millimeter, and each of these measurements shall be recorded as W2.

A.2.6 The change in dimension at each of the three locations shall be calculated and expressed as a percentage using the formula [(W2-W1)/W1]×100.

A.2.7 The webbing shall be rejected, if, at any one of the measured points, there is a decrease in its width of more than –10% for webbings of nominal width less than or equal to 100 mm, and –12% for webbings of nominal width over 100 mm.

A.3 Test to verify the basic working load of a sewn webbing component

A.3.1 Endless sewn webbing components

The specimen shall be mounted straight and without twist to the test machine, and shall be subjected to a force equivalent to not less than seven times its basic working load.

A.3.2 Sewn webbing components with eyes

The specimen shall be mounted straight and without twist between the pins of the test machine. The diameter of the pins or bollards shall be such that the included angle of the eyes of the specimen is not less than 10° nor greater than 20°. The specimen shall be subjected to a force equivalent to not less than seven times its basic working load.

A.3.3 Sewn webbing components with fittings

The specimen shall be mounted straight and without twist between the pins of the test machine. The pins shall not be deformed during the test. The specimen shall be subjected to a force equivalent to not less than five times its basic working load.

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